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SPIRIFERACEA OF THE CEDAR VALLEY LIMESTONE OF IOWA

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ABSTRACT—Twenty-three species of Cedar Valley brachiopods are described and illustrated, seven of them as new forms. One new genus, *Eosyringothyris*, is proposed and three others, *Spinocyrtia*, *Tylothyris* and *Ambothyris*, are first recognized as represented in the formation.

THIS is the final paper on the brachiopod fauna of the Cedar Valley limestone. Thus the study and collecting of twenty years is brought to fruition. Probably most of the species present in the exposed portions of the formation have come to light, as several years have passed since a new form has been found. However several species are represented by poor specimens in our collections and await discovery of better examples before study and publication. A later paper will contain a summary of the stratigraphy of the Cedar Valley and a discussion of the occurrence therein of the various species and their bearing on the correlation of the formation.

These brachiopods, formerly placed in the genus *Spirifer*, are prominent members of the fauna and the largest examples of this group of animals found in the beds. However they are not as abundant specifically or individually as the Atrypae and the Stropheodontae. As far as now known most of the species are confined to the Cedar Valley of Iowa and its extensions into Illinois and Minnesota. The other genera are usually represented in most zones by one or more species but individually are less common except locally than *Spinocyrtia*. *Tylothyris* is best represented in the basal beds. *Ambothyris* is exceptional as it has only one species, which is confined to a single layer near the middle of the Solon member (Stainbrook, 1941, p. 323). With few exceptions these brachiopods have limited vertical ranges, have easily recognized external features, and are of great assistance in working out the stratigraphy of the formation.

The spiriferoid brachiopods described and illustrated herein reinforce the previous correlations of the Cedar Valley made in other papers of the writer. In the Milwaukee formation of Wisconsin occur *Spinocyrtia iowensis* (Owen), *Eosyringothyris occidentalis* (Swallow), *Tylothyris subvaricosa* (Hall and Whitfield), and *Cyrtina triquetra* Hall. *Spirifer euruteines milwaukeensis* Cleland is distinct from the Iowa *Spinocyrtia euruteines*. *Spirifer pennatus* Cleland appears to be more nearly related to *Tylothyris bimesialis* Hall than it does to *Spirifer pennatus* Atwater of the Hamilton. It is smaller, proportionately thicker, differently shaped, has a higher area and a narrower nonsinuate

fold. In the present writer's opinion this form cannot be considered identical with *Spirifer pennatus arkonensis*. *Spirifer pennatus* also is not a member of the genus *Spirifer* as it is now defined by authors, but is closest to *Tylothyris*. It has the general shape of members of that genus, the lamellose exterior, the low pedicle palintrope and the well-developed delthyrial callus. The main difference is the lack of a well-developed septum in the pedicle valve but even in this species there is a slight subacute median ridge. That this Middle Devonian species should not have as well-developed a median septum as the Mississippian repretative is to be expected. Our Upper Devonian forms show the septum in various stages of development.

The correlation of the Cedar Valley with the Callaway limestone of Missouri is strengthened by the common occurrence in the two formations of *Cyrtina missouriensis* (Swallow), *Ambothyris halli* (Branson), *Eosyringothyris occidentalis* (Swallow), *Eosyringothyris thomasi* Stainbrook and *Tylothyris annae* (Swallow). *Spinocyrtia euruteines* (Owen) also occurs commonly in equivalent strata near Annada, Missouri, but the form reported under this name from the *Snyder Creek* shale is distinct. *Tylothyris annae* also occurs in the Snyder Creek shale. The *Cyrtina hamiltonensis* Branson of the Mineola appears to be near *Cyrtina triquetra* of the *Cedar Valley* and *Cyrtina triquetra* Branson from the Snyder Creek shales is a different form. *Spirifer subvaricosus* Branson and *Spirifer varicosus* Branson from the Mineola are probably representative of *Tylothyris subvaricosa* (Hall and Whitfield).

The Devonian limestone outcropping in Calhoun county, Illinois, is apparently the southern extension of the Cedar Valley and has yielded *Spinocyrtia iowensis* (Owen), *Spinocyrtia cedarensis* (Owen) and probably *Spinocyrtia parryanus*. *Spirifer wortheni* was described by Hall (1857, p. 156) from Devonian limestone near Hamburg, Illinois, and is very similar in appearance to *S. parryanus*. If further collecting should demonstrate their specific identity, the name *Spirifer parryanus* must be suppressed, as the other name has priority.

Although the Cedar Valley is persistently correlated with the Hamilton by authors generally, the spiriferoid brachiopods lend little support to this view. The present writer has investigated as far as possible reports of occurrence of Cedar Valley species in formations of that age or Hamilton forms in strata correlated with the Cedar Valley. In most instances collections were made from the main Hamilton areas of the Mississippi valley and of formations of Cedar Valley age in states adjoining Iowa.

The *Spirifer euryteines* illustrated by Miss Stewart (1927) as occurring in the Silica shale of Ohio is specifically distinct from the true Iowa *euruteines*. The Ohio form is wider, shorter, has more extended angles, a narrower, higher fold, narrower and more acutely convex plications, and a pedicle palintrope which is lower and generally apsacline instead of slightly procline.

In the middle part of the Gravel Point member of the Traverse near Charlevoix, Michigan, occurs a large *Spirifer* (*Spinocyrtia*) with slender, greatly extended angles. It is superficially like *Spinocyrtia iowensis* (Owen) but differs in having a lower and rounded instead of angular fold, fewer and larger plications, and a lower, more curved pedicle palintrope. Although not identical, the Iowa and Michigan forms appear to be related as members of an evolutional series.

In the Partridge Point member of the Traverse beds near Alpena, Michigan, occurs a small *Tylothyris* which resembles *T. annae* (Swallow). However close examination shows the Michigan form to be differently shaped, with strongly curved lateral margins, sharp angles, and extended hingeline, and to have an almost procline, more curved pedicle palintrope.

Various other Hamilton species of *Spirifer* have been reported from the Devonian of Milwaukee and Missouri. But in extensive collections from these areas now at hand no typical Hamilton form was detected. Likewise in fairly extensive collections of fossils from the Middle Devonian of Michigan, Ontario, and southern Indiana the writer was unable to find any Cedar Valley form of spiriferoids.

Specimens with the designation S.U.I. are in the collections of the State University of Iowa. Those marked M.A.S. are at present in the possession of the writer but will soon be placed in the repository of the Univer-

sity as this study is near completion. Figures on the plates are natural size unless otherwise noted. Illustrations are from specimens coated with ammonium chloride, and a few have been retouched.

The cross sections of the posterior portions of the several species were not made at regular and measured intervals but wherever changes appeared to be most significant. The pedicle valve is uppermost in the diagrams.

Three groups of Spiriferoids are readily distinguishable in the Cedar Valley brachiopods. One group of six species, typified by *Spirifer iowensis* Owen, is abundantly represented in all zones and contains the largest brachiopods of the formation. Most of the species of this group have come to the attention of previous workers in this area, —only one, *Spirifer* (*Spinocyrtia*) *brandonensis*, is new. Although differing in many specific details they agree in features of generic importance, and they apparently are thus nearly related. These generic characters may be summed up in the following discussion.

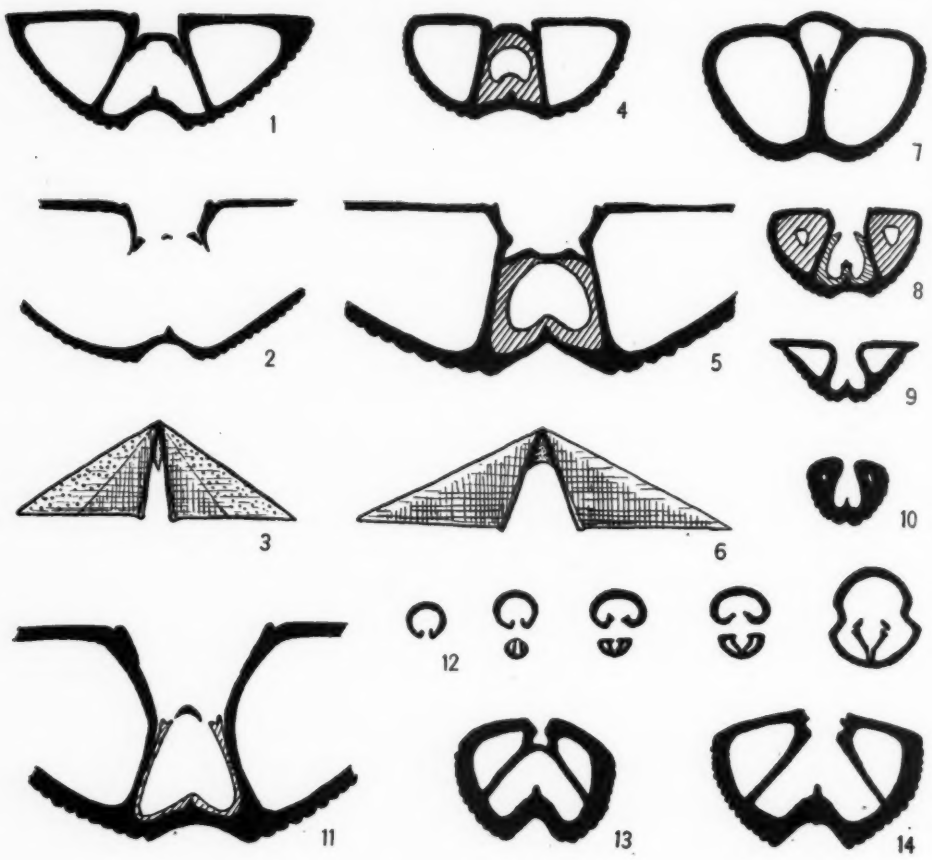
Genus SPIRIFER Sowerby, 1815
Subgenus SPINOCYRTIA Fredericks, 1916

Shall large, strongly and unequally biconvex, spiriferoid in shape, with the extremities round to angular or greatly extended. Hinge line long, equalling or less than the greatest breadth. Fold and sinus strongly developed, rounded to angular, variable in height or depth, extending from beak to the front margin, unplicate although examples of several species display suggestions of incipient plications. Lateral slopes marked by numerous strong simple plications, variable in height, flat to angular, and separated by linear furrows or deep grooves. Pedicle beak strong pointed, extended and greatly to slightly incurved. Palintrope high, vertically and horizontally striated, slightly to strongly curved, generally apsacline to catacline, seldom procline; divided into three areas as in *Syringothyris*, the region divided by the delthyrium being horizontally and vertically striated, and those beyond being narrower and transversely marked only. Delthyrium large, open to the apex; no deltidium was observed in any example at hand. Brachial palintrope well developed, low, flat or curved, divided by a broad low notothyrium.

Internally in the pedicle valve the delthyrial supporting plates are strongly developed but variable in length. In some species they extend along the floor of the valve halfway to the anterior margin. The plates are concavely arched toward the angles and concave toward the front. They are greatly thickened directly below the teeth and slightly excavated near the edges of the palintrope, so that small shelflike extensions project there. The junction of the plates with the palintrope is indicated by a groove along each edge of the delthyrium. A transverse delthyrial plate of variable length and thickness extends forward from the apex formed by the posterior junction of the supporting plates; it is concave anteriorly and outwardly flat or convex. In some species the cavity beneath the plate may be nearly filled with deposits of adventitious calcareous tissue. The muscle scars are large, extend to the midpoint or nearly so, are pyriform in outline, and are radially grooved, in some instances longitudinally. The adductor scars are long, narrow and separated by a low median septum. This, although not attaining a height of more than a millimeter, is strongly developed in some species, wide, and extended beyond the midlength.

In the interior of the brachial valve the cardinal process is large, subquadrate to semielliptical in outline, broadly convex and vertically grooved. The sockets are long, narrow and deep. The socket plates strong curved and concave outwardly. Muscle area large and extended beyond the midpoint. The posterior adductors are short and arcuate laterally. The anterior adductors are long, narrow, and extend beyond them two or three millimeters. Between them is a long narrow median septum, which varies in height and strength in examples of the same species.

Exterior of both valves excepting the palintropes marked by numerous fine radiating costae, which bear on their summits abundant spinose papillae. In some species the radiating costate may be absent or poorly developed in the interplicational furrows. The papillae are evident only in well-preserved specimens. In many the radial



EXPLANATION OF FIGURES 1–14

(All diagrams are enlarged 2½ times)

FIGS. *1–3—Eosyringothyris aspera* (Hall). *1, 2,* Transverse sections of the posterior portion of a pedicle valve showing the transverse delthyrial plate, its anterior point, and the median septum. *3,* Diagrammatic view of the pedicle palintrope showing the divisions, the markings, and the form of the transverse delthyrial plate. (p. 432)

4–6—Spirifer (*Spinocyrtia*) *iowensis* Owen. *4, 5,* Transverse sections of the posterior portion of a pedicle valve showing the transverse plate and the median septum. (In the diagrams the shell proper is shown in black and depositional material by diagonal lines.) *6,* Diagrammatic view of the pedicle palintrope showing its markings and the form of the transverse delthyrial plate. (p. 421)

7—Cyrtina robusta Stainbrook, n. sp. A section of the posterior of a pedicle valve. (p. 449)

8—Tylothyris inutilis (Hall). A section of the posterior portion of a pedicle valve anterior to the short delthyrial plate and showing the deposition of much shell material. (p. 440)

9—Tylothyris bimesialis (Hall). A section of the posterior of a pedicle valve showing the median septum. (p. 438)

10—Tylothyris subvaricosa (Hall). A section of the posterior of a pedicle valve. (p. 443)

11—Eosyringothyris thomasi Stainbrook, n. sp. A section of the posterior portion of a pedicle valve. (p. 433)

12—Ambothyris halli (Branson). A series of five cross sections of the posterior portion of a specimen showing the close approximation of the septa of the brachial valve. (p. 450)

13, 14—Tylothyris subattenuata (Hall). Two sections of the posterior portion of a pedicle valve showing the short transverse delthyrial plate and the median septum. (p. 441)

costate have been obliterated by wear, lack of preservation, or unskillful cleaning.

Generally these species have been placed in *Spirifer* s. l. In recent years this genus has been repeatedly divided into many genera by Fredericks, Grabau and others. From *Spirifer*, restricted, the species of this group differ in having a nonplicate fold and sinus. We have not seen examples of the genotype of *Spirifer* and therefore have not been able to study its generic characters at first hand. Accepting Frederick's determinations, *Spirifer* appears to have well-developed delthyrial supporting plates, a moderate median septum in the pedicle valve, but no transverse delthyrial plate. Our species, consequently differ from *Spirifer*, in this respect as they all have well-developed plates. However, Davidson (1858) in his summary of the generic characters of *Spirifer* states that the ventral delthyrium is always more or less closed by a pseudodeltidium notched in the vicinity of the cardinal edge. His illustrations of pedicle valves of *Spirifer striatus* (Martin) plainly show a transverse delthyrial plate. Also the median septum of the pedicle valve of our species apparently is not as highly developed. But Dunbar and Condra do not mention a pedicle median septum in their diagnosis of *Spirifer*. The fine radial costae of our species are less numerous and apparently differ also in having spinose papillae.

Spinocyrtia was proposed by Fredericks (1916) with *Delthyris granulosa* Conrad as the genotype. With this species our forms agree in nearly all the generic details. The shape, the unplicate fold and sinus, the presence of simple plications on the slopes, the features of the palintropes and of the delthyrium and notothyrium are all similar. *S. granulosus* has finer and more numerous radial costae, which are somewhat discontinuous, and its spinose papillae have longer bases. It also has a sinus on the brachial fold, but *S. brandonensis* has a similar well-developed sinus on the fold, and *S. cedarensis* has a slightly developed one. In *S. granulosus* the transverse delthyrial plate is longer, and there are much larger deposits of calcium carbonate in the posterior chambers of the pedicle valve. *S. granulosus* has a low median septum in the brachial valve and a suggestion of one in the pedicle. Our species are referred to *Spinocyrtia* with considerable assurance.

In 1924 the genus *Platyrachella*, based on *Spirifer macbridei* Calvin, was proposed by Fenton and Fenton (1924, p. 158). Diagnostic characters were stated to be the presence of a well-defined delthyrial plate and impunctate shell structure. Several species besides the genotype were referred to this new genus, among them *Spirifer asper* Hall, which is shown below to be quite distinct. *Spirifer iowensis* was placed by Belanski (1928, p. 207) in *Platyrachella* and its characteristics have necessarily been investigated. They agree in nearly all particulars with those of our species and with *Spirifer granulosus*. The main difference is the strong plication in the sinus of the pedicle valve of *Spirifer macbridei*. As *Spinocyrtia* antedates *Platyrachella* our species are appropriately referred to it rather than to the latter genus. *Platyrachella* may be distinguishable from *Spinocyrtia* and *Spirifer* but not on the basis of impunctate shell structure or the presence of a transverse delthyrial plate. Spiriferoids with multiplicate fold and sinus such as *Spirifer whitneyi* Hall are referable to *Cyrtospirifer* Nalivkin (1918) which also has a delthyrial plate and impunctate shell substance. To *Platyrachella* should be referred those spiriferoid shells with delthyrial plates and a distinct single plication in the sinus of the pedicle valve. *Platyrachella ballardi* Belanski of the Shellrock is another representative.

SPIRIFER (SPINOCYRTIA) IOWENSIS Owen
Plate 65, figures 1–5, 10; text figures 4–6

Spirifer iowensis OWEN, 1852, Geol. Survey Wisconsin, Iowa and Minnesota, p. 585, pl. 3, fig. 1.
Spirifer pennatus OWEN, 1852, idem, p. 585, pl. 3, figs. 3, 8.
Spirifer ligus OWEN, 1852, idem, p. 585, pl. 3, fig. 4; pl. 3A, fig. 2.
Spirifer pennata, HALL, 1858, Report on the geological survey of the State of Iowa . . . , vol. 1, pt. 2, p. 510, pl. 5, fig. 1.
Spirifer ligus, HALL and CLARKE, 1893, New York Geol. Survey Paleontology, vol. 8, pt. 2, pp. 31, 39, pl. 22, figs. 19–24; pl. 29, fig. 13.
Spirifer atwaterana MILLER, 1878, Davenport Acad. Sci. Proc., vol. 2, p. 222.
Spirifer atwaterana, MILLER, 1889, North American Paleontology and Geology, p. 372.
Spirifer iowensis, (part) SCHUCHERT, 1897, U. S. Geol. Survey Bull. 87, p. 393.

Platyrachella iowensis, BELANSKI, 1928, Am. Midland Naturalist, vol. 11, p. 167, footnote p. 207.

Shell large, subequally biconvex, subsemielliptical to subtriangular in outline with long nearly straight or curved anterolateral margins and short truncate front margin, much wider than long, the greatest width along the hinge line, the cardinal angles greatly extended and acuminate. With maturity the shells become thicker, longer in proportion to width, and curved along the anterolateral margins near the extremities. The dimensions of several hypotypes are: length 25.8 mm., 28.3 mm., 39.7 mm., and 41.7 mm.; width 84.6 mm., 83.2 mm., 98.1 mm., and 86.2 mm. (incomplete); thickness 18.8 mm., 25.1 mm., 31.7 mm. and 37.9 mm.

Pedicle valve moderately convex, the greatest convexity in the umbonal region, regularly arched from beak to front along the bottom of the sinus with the curvature increasing with age, moderately convex transversely in the middle portion, and depressed toward the angles. Sinus sharply defined at the sides, extending from beak to the front margin, broad, deep, nonplicate; the sides flat or gently convex, meeting at the bottom sharply in an obtuse angle, and marked near their outer margins by a well-defined narrow groove. Lateral slopes gently curved from the hinge line to the anterolateral margins and more strongly curved from the borders of the sinus to the angles, gently depressed in front of the cardinal extremities and elevated into a shelflike ridge along each cardinal margin. On each slope are from 20 to 25 or more strong, low, broad, gently rounded, simple plications, which become smaller and more rounded toward the angles; only those adjacent to the sinus reach the beak, the others swing toward the cardinal margins at progressively lower angles. Beak strong, sometimes slightly twisted, pointed, incurved, and extended beyond the hinge line. Palintrope high, flat for the greater part, strongly curved beneath the beak, the inferior portion horizontally and vertically striated and catacline; the lateral margins sharply defined, sloping rapidly from the beak for a short distance on either side and then maintaining a moderate height beyond the umbonal region nearly to the extremities; on either side along the borders of the pedicle opening is a well-defined narrow groove, possibly indicating the former presence of a deltidium; delthyrium large, about as wide as high. Internally the delthyrial supporting plates are strongly developed, heavy, thickened toward the area, concavely arched toward the cardinal extremities and anteriorly, and extending along the floor of the valve almost to the midlength. The inner surfaces are concave and bounded by slight ridges at the edges of the palintrope. Between the posterior ends of the supporting plates is a flat delthyrial plate, concave toward the front and parallel to the plane of the valve; the cavity below is usually filled with a calcareous deposit; along the medial line there is a slight mesial septum.

Brachial valve shorter and less convex than the pedicle, arched along the summit of the fold, with the greatest curvature posterior to the midlength, strongly convex transversely in the middle, depressed toward the extremities, and highest along the fold. Fold nonplicate, strongly developed, originating at the beak, becoming wider and higher toward the front, the sides nearly flat or gently convex, angular along the summit, elevated above the remainder of the valve, sharply defined at the sides by deep narrow furrows, and truncated at the front by the mesial extension of the opposite valve. Lateral slopes regularly arching from the hinge line to the angles, marked by plications similar to those of the pedicle valve. Umbonal region gently convex; beak small, incurved, and a little projecting. Palintrope low, maintaining the same height nearly to the extremities, flat or gently concave, and at right angles to the opposite area; notothyrium low, much wider than high. A few specimens show the presence of a median septum internally.

Surface of both valves marked by fine concentric lines of growth, of which occasional ones may be more pronounced; in some specimens they are crowded toward the front. The fold, sinus and plications and interplication spaces are marked by numerous fine radial costae, which with the growth lines give a characteristic reticulate appear-

ance to the surface of well-preserved specimens. Each costa has a papillated aspect. The papillae are situated on the elevated portions of the costae between the depressions formed by the intersection of the growth lines.

Spirifer iowensis is one of the abundant forms of the Cedar Valley beds and may be collected in numbers at several localities. Complete specimens are difficult to secure as the extended cardinal angles usually break during extraction, and the rough external surface causes the matrix to adhere closely. The species has an extended vertical and horizontal range and shows considerable variation at different localities and horizons in the length, thickness, and extension of the hinge line. However it is easily recognized by several features: the greatly extended angles, the large size, and the angularity of the fold and sinus.

The species has had a varied history since its description by Owen, and it has since been given several designations. The generally used specific name, *Spirifer pennatus*, was discovered by S. A. Miller to be preoccupied by *Terebratula pennata* Atwater (the species long known as *Spirifer mucronatus* (Conrad)) and he proposed to call Owen's species *Spirifer atwaterana*. Hall and Clarke, recognizing that *Spirifer pennatus* Owen was a synonym, placed the species in *Spirfer ligus* Owen. Schuchert included both *Spirifer pennatus* Owen and *Spirifer ligus* Owen in *Spirifer iowensis*. An examination of Owen's type specimens preserved in the National Museum shows that the specimen of *Spirifer iowensis* is not well preserved and not easily compared with the forms at hand; it is however like the *Spirifer pennatus* Owen. The type specimens of *Spirifer pennatus* Owen on the other hand are better preserved and are readily identifiable with specimens collected along the Iowa River. The examples of *Spirifer ligus* Owen appear to differ little from *Spirifer pennatus* Owen and represent one of the variations notable for greatly extended angles, nearly straight anterolateral margins and shorter shell. *Spirifer cedarensis* is a different species. Examination of the interior of *Spirifer pennatus* (Atwater) (*Delthyris mucronatus* Conrad) shows it to possess a small delthyrial plate and a median septum in the pedicle valve; these characteristics with the lamellose exterior may place it in the genus *Tylothyris* North.

Occurrence.—Cedar Valley limestone in all zones from the *independensis* to *waterlooensis*. The type locality is at Aicher's quarry in Johnson county north of Iowa City. It has been collected at Buffalo, Davenport, Iowa City, various localities in Johnson county, Ely, Cedar Rapids, Linn Junction, Vinton, Brandon, Independence, Littleton, Waterloo, Waverly and elsewhere.

Types.—Holotype is 17925 U. S. Nat. Mus.; paratypes 17919, 17920; hypotypes, S.U.I. 6–254, 6–438, 6–292, 6–241 and M.A.S. 231, 235, 282 and 324.

SPIRIFER (SPINOCYRTIA) EURUTEINES Owen

Plate 67, figures 1–6, 8, 9

Delthyris euruteines OWEN, 1844, Rep. Geol. Expl. Iowa, Wisconsin, and Illinois, p. 69, pl. 12, fig. 9.
Spirifer euruteines, OWEN, 1852, Geol. Survey Wisconsin, Iowa and Minnesota, p. 586, pl. 3, fig. 6a, b, not fig. 2.
Spirifer euruteines, SCHUCHERT, 1897, U. S. Geol. Survey Bull. 87, p. 389.
Spirifer parryana CALVIN (part), 1888, Iowa Univ. Lab. Nat. History Bull. 1, p. 19.

Shell medium-sized to large, subequally biconvex, subelliptical to subquadrate in outline, the cardinal angles usually not extended, but sometimes slightly so, and the lateral margins broadly rounded toward the front and joining the cardinal margin at right angles, wider than long, the hinge line sometimes equaling and sometimes less than the greatest width. Dimensions of several typical specimens are: length 23.1 mm., 27.5 mm. and 37.5 mm.; width 39.1 mm., 41.3 mm. and 59.7 mm.; thickness 21.3 mm., 24.1 mm. and 37.7 mm.

Pedicle valve strongly convex, with the greatest convexity in the umbonal region, regularly arched along the midline with decreasing curvature to the front margin, strongly and evenly arched transversely. Sinus originating at the beak, broad, deep, regularly concave from side to side, unmarked by distinct plications, distinctly defined at the sides but merging with the bordering plications, extended at the front; near the outer margin of each side is a narrow

linear furrow, in some specimens two, the spaces thus delimited seem to be incipient plications. Lateral slopes moderately and regularly curved from the hinge line to the anterolateral margins and sloping strongly from the sinus to the extremities; each marked by 17 to 20 plications. Plications simple, broad, low, broadly depressed convex to nearly flat, separated by shallow, distinctly linear furrows, largest near the sinus and decreasing regularly in size toward the angles, where they swing in toward the cardinal margin at successively lower angles. Umbonal region elevated, strongly convex, and a little extended. Beak large, pointed, incurved, and extended a short way beyond the hinge line. Palintrope large, high, slightly apsacline, the lateral margins sloping rapidly from the beak to the extremities, flat for the greater part, curving slightly beneath the beak, marked by fine transverse and longitudinal striae and by deep narrow grooves along the lateral borders of the opening. Delthyrium large, higher than wide, supported at the sides by strong delthyrial supporting plates. Transverse delthyrial plate strong, flat or gently convex, concave toward the front, and inclined at an angle of 45° to the plane of the valve. Brachial valve shorter and less convex than the pedicle, arching from beak to front with increasing curvature over the umbo, moderately and regularly arched transversely, slightly depressed toward the cardinal angles. Fold extending from beak to front, gently but regularly convex from side to side, elevated but little above the remainder of the valve, nonplicate, broad and slightly truncate at the front, distinctly defined laterally by narrow furrows. Lateral slopes curving regularly and with moderate rapidity to the anterolateral margins and more rapidly from the fold to the lateral margins, bearing plications similar in appearance to those of the pedicle slopes. Umbonal region gently convex and a little extended. Beak broad, a little incurved and projecting. Palintrope low, decreasing in height gradually to the extremities, vertically striated, gently curved, and divided by a broad low notothyrium. A thin low median septum is present.

Fold and sinus marked by numerous fine radiating costae, variable in number, increasing by intercalation, and separated by spaces which may be less than or as much as twice as wide as one costa. The plications are similarly marked, but the costae are closer together and number from four to seven on each plication; where the surface is well preserved the costae are marked throughout by numerous spinose papillae. Growth lines few, occasionally pronounced enough to interrupt the continuity of the costae. Between the growth lines abundant finer striae cross the costae, being more pronounced in the intercostal areas and in the furrows between the plications, and giving a reticulate appearance to the well-preserved surface of the shell.

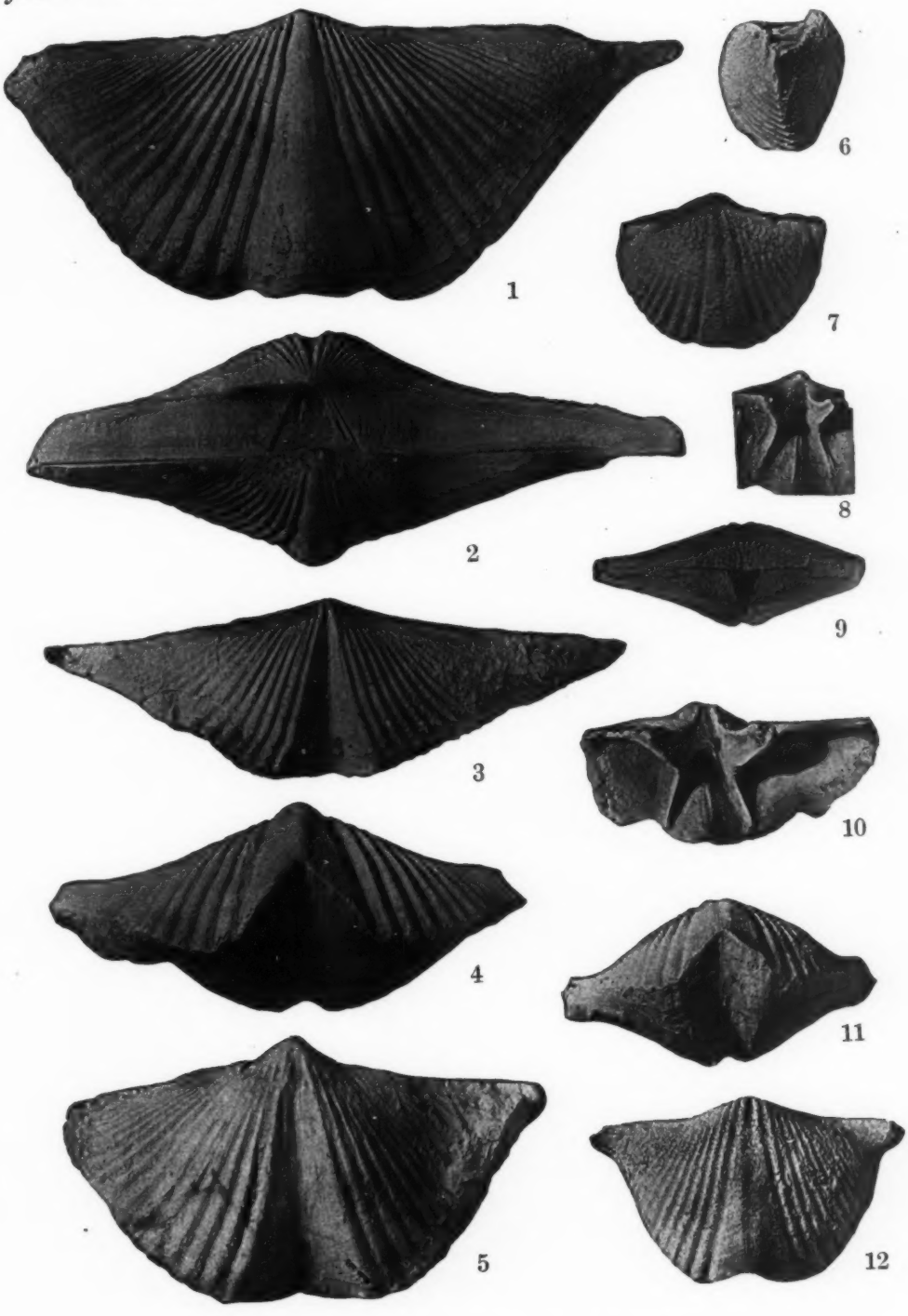
Spirifer euruteines is characterized by its dictinctly flat plications separated by linear furrows, by the broad gently convex low fold, which rises but little above the arch of the valve, by the broad rounded sinus, and by the short cardinal angles.

The species was illustrated by Owen in 1844, but no description was given. In 1852 Owen described it and again figured it in plate 3, figure 6; he also figured an internal mold, plate 3, figure 2, as being of the same species. Hall in 1858 described two additional species from the Cedar Valley, *Spirifer parryana* and *Spirifer capax*, the latter from internal molds similar in all respects to Owen's figure 2. Calvin gave a good description of *Spirifer parryana* and placed *Spirifer capax* in synonymy with it. However his specimens are at hand and included fine examples of *Spirifer euruteines* Owen as well

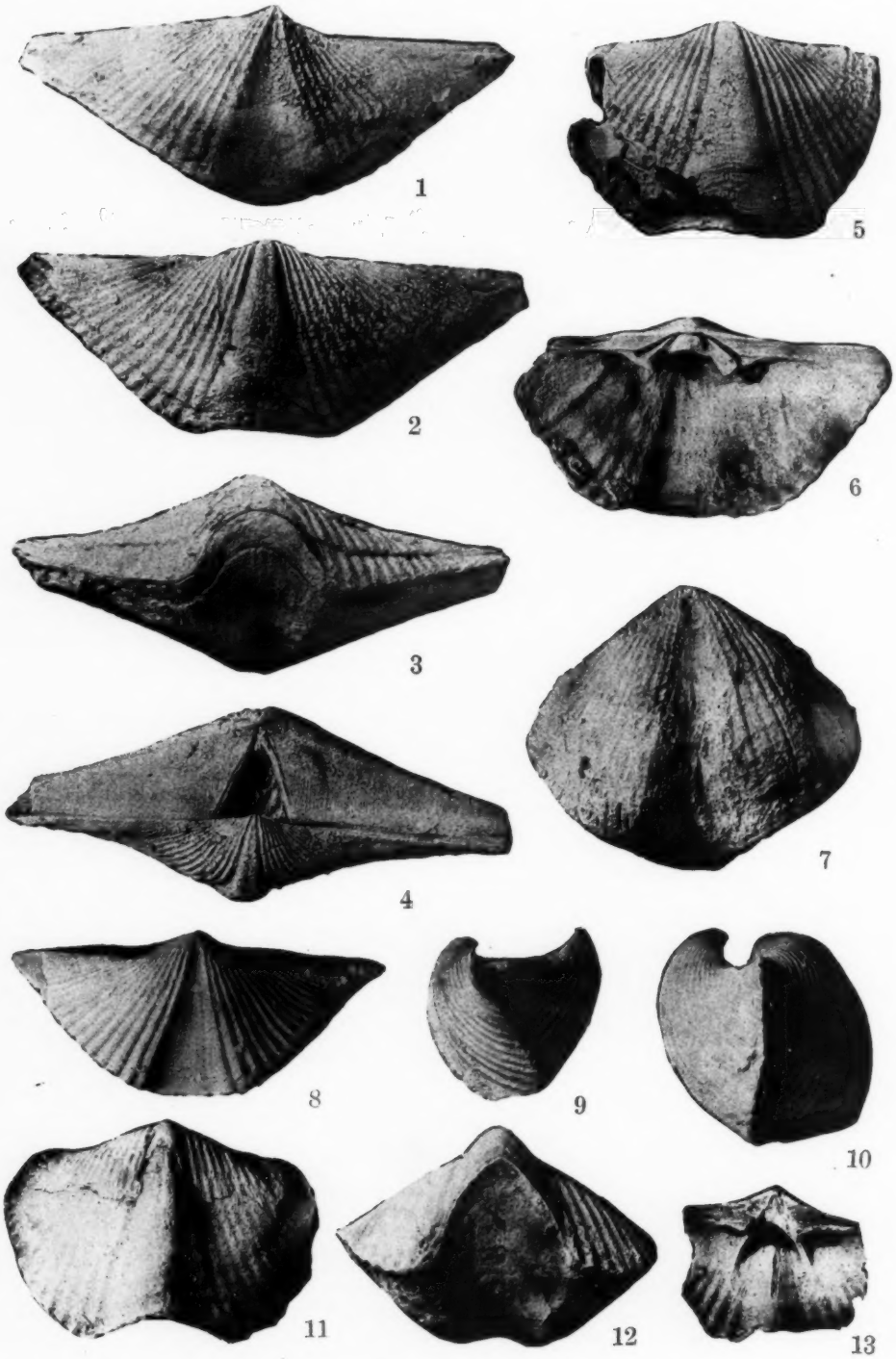
EXPLANATION OF PLATE 65

FIGS. *1–5, 10—Spirifer* (*Spinocyrtia*) *iowensis* Owen. *1, 2*, Brachial and posterior views of a hypotype (S.U.I. 6-438b), Independence, Iowa. *3*, Pedicle view of another (S.U.I. 6-234), Waverly, Iowa. *4, 5*, Anterior and pedicle views of a specimen, Independence, Iowa. *10*, Internal view of a pedicle valve showing transverse delthyrial plate (M.A.S. 328), Waverly, Iowa. (p. 421)

6–9, 11, 12—Spirifer (*Spinocyrtia*) *brandonensis* Stainbrook, n. sp. *6, 7*, Lateral and brachial views of a paratype. *8*, Internal view of a pedicle valve showing transverse plate and median septum. *9*, Posterior view of a paratype. All (S.U.I. 6-300) from Littleton, Iowa. *11–12*, Anterior and brachial views of the holotype (M.A.S. 121), Brandon, Iowa. (p. 429)



Stainbrook, Devonian Brachiopoda



Stainbrook, Devonian Brachiopoda

as *S. parryanus*. Schuchert found among the specimens in the National Museum the type of *Spirifer euruteines* and with it the internal mold mentioned above. This latter specimen Schuchert correctly determined was the same as *Spirifer capax*, and he, recognizing Calvin's union, placed both *Spirifer capax* and *Spirifer parryana* in synonymy with *Spirifer euruteines* Owen. Comparison and study of the type specimen of *Spirifer euruteines* in the National Museum and of the type of *Spirifer parryanus* in the American Museum indicate them to be distinct.

Occurrence.—Cedar Valley limestone, typically in the *Stropheodonta parva* zone and the *Pentamerella* zone at Buffalo, Moscow, Linwood and Atalissa. In limestone containing the same form at Annada, Mo. This species has been reported by Branson from the Snyder Creek shale of Missouri. Comparison of specimens from that formation with *S. euruteines* of Iowa shows that the Missouri species is distinct.

Types.—Holotype U. S. Nat. Mus. 17924; hypotypes S.U.I. nos. 6–255 and 6–288, M.A.S. 71, 74, 1376, and 1418.

SPIRIFER (SPINOCYRTIA) CEDARENSIS Owen

Plate 66, figures 1–6, 8, 9, 13

Spirifer cedarensis OWEN, 1852, Geol. Surv. Wisconsin, Iowa and Minnesota, p. 586, pl. 3, fig. 5.

Spirifer iowensis OWEN (part). SCHUCHERT, 1897, U. S. Geol. Survey Bull. 87, p. 394.

Shell large, subequally biconvex, wider than long, with the greatest width along the hinge line, proportionately longer in mature specimens, subelliptical in outline, the cardinal extremities angular and more or less extended, especially in immature specimens, the anterolateral margins long and nearly straight, the front margin short and gently concave. Measurements of several hypotypes are: length 27.4 mm., 30.4 mm., and 31.3 mm.; width 49.7 mm., 61.4 mm. (incomplete), and 63.5 mm.; thickness 26.6 mm., 30.5 mm., and 32.5 mm. Two less mature specimens measure 28.8 mm. and 25.5 mm. in length, 69.8 mm. and 70.5 mm. in width, and 28.1 mm. and 25.5 mm. in thickness.

Pedicle valve strongly convex, with the greatest curvature in the umbonal region, the surface arching rapidly thence to the front and lateral margins, evenly and regularly curved from beak to front, more strongly convex transversely in the middle and depressed more or less toward the extremities. Sinus continuous from the beak to the front margin, deep and wide, nonplicate, the bottom gently concave or flattened and distinctly separated from the steeply sloping sides by long, narrow furrows, and considerably extended at the front. Lateral slopes gently curved from the cardinal margin to the front and sloping rapidly from the borders of the sinus to the hinge extremities, sometimes depressed in front of the angles, with a shelflike extension along the cardinal margins. Plications simple, strong, subangular, separated by narrow, subangular furrows, numbering about 18 on each slope and decreasing in size toward the angles. Beak short, pointed, a little incurved and projecting, sometimes slightly twisted. Palintrope high, transversely and longitudinally striated, flat for the greater part, more or less curved apically, a little procline in less mature specimens and catacline or apsacline in gerontic examples, showing along the delthyrial margin on either side a narrow groove. Internally beneath the sides of the opening are two strong delthyrial supporting plates, which drop sharply from the hinge teeth to the floor of the valve, along which they extend nearly to the midlength. Between them is a thick transverse delthyrial plate, concave toward the hinge line and situated at right angles to the plane of the valve. A faintly developed median septum separates the muscle scars.

EXPLANATION OF PLATE 66

FIGS. *1–6, 8, 9, 13*—*Spirifer* (*Spinocyrtia*) *cedarensis* Owen. *1–4*, Pedicle, brachial, anterior, and posterior views of a hypotype (S.U.I. 6-272A). *5*, Brachial view of a narrower example (M.A.S. 341). *6*, Internal view of a brachial valve (M.A.S. 341). *8, 9*, Pedicle and lateral views of another hypotype (M.A.S. 1383). *13*, Internal view of a pedicle valve (M.A.S. 1380). All from the *bellula* zone, Brandon, Iowa. (p. 425)

7, 10–12—*Spirifer* (*Spinocyrtia*) *parryanus* Hall. *7*, Pedicle view of a hypotype (M.A.S. 1381), *cedarensis* zone, Quasqueton, Iowa. *10–12*, Lateral, brachial, and anterior views of another (M.A.S. 1375), Brandon, Iowa. (p. 426)

Brachial valve less convex than the pedicle, highest in the middle, strongly arched along the crest of the fold from the beak to the midpoint and gently to the front margin, evenly and moderately convex in the central portion and depressed toward the cardinal angles. Fold originating at the beak and widening to the front margin, elevated above the remainder of the valve, sharply defined by a strong furrow on either side, transversely flattened or gently convex along the crest for the greater part and sloping sharply at the sides, displaying in some specimens a faint mesial depression in the umbonal portion, and shortened at the front by the extension of the pedicle sinus. Lateral slopes gently and regularly curved from the hinge line to the front and sloping with moderate rapidity from the fold to the extremities, slightly depressed in front of the angles, bearing plications similar to those of the opposite valve. Beak short, blunt, incurved. Palintrope low, with subparallel margins, gently curved, situated in the plane of the valve, and divided by a broad low notothyrium. Internally the cardinal process is strong and low, the sockets are deep and narrow, and the socket plates well developed.

The surface of both valves is marked by numerous fine concentric striae of growth and by a few strong lamellose lines, usually crowded at the front margins of mature individuals. Plications, fold and sinus marked by fine radiating costae, which are papillose throughout their length. Surface of well-preserved specimens has a finely reticulate appearance. Immature specimens are usually much wider than long, with extended angles. With maturity the shell becomes proportionately thicker and longer, and the angles less extended.

The holotype of *Spirifer cedarensis* is a pediele valve but displays the distinguishing characteristics of the species: large size, extended angles, large cardinal area, and gently concave sinus. From *Spirifer icwensis* it differs in having the fold and sinus distinctly rounded instead of angular, in having a higher and less curved pedicle palintrope, the delthyrial plate more elevated, longer, stouter, and generally at right angles to the plane of the valve. From *Spirifer parryanus* it differs in the greater extension of the cardinal angles, in the higher, only slightly curved pedicle palintrope, in the nonangular fold and sinus, and in having the greatest width along the hinge line.

Occurrence.—Cedar Valley limestone in the *profunda* zone at Brandon and Littleton, *bellula* zone at Buffalo and Brandon, and *Cranaena* zone at Randalia; also occurs in these zones elsewhere.

Types.—Holotype U. S. Nat. Mus. 17923; hypotypes S.U.I. 6–240, 6–242, 6–239, and 6–272, and M.A.S. 341, 150, 280, 342, and 237.

SPIRIFER (SPINOCYRTIA) PARRYANUS Hall

Plate 66, figures 7, 10–12

Spirifer parryana HALL, 1858, Geol. Surv. Iowa, vol. 1, pt. 2, p. 509, pl. 4, fig. 8.
Spirifer parryana (part) CALVIN, 1888, Iowa Univ. Lab. Nat. History Bull. 1, pp. 11, 19.
Spirifer parryanus, HALL and CLARKE, 1893, New York Geol. Survey Paleontology, vol. 8, pt. 2, pp. 29, 31, 39, pl. 22, figs. 8, 9, 15–17.

Shell medium-sized to large, strongly but inequally biconvex, transversely subelliptical, wider than long, with the length increasing proportionately in maturer shells, the hinge line equal to, less than, and often considerably less than the greatest width, cardinal extremities a little auriculate and extended in young specimens and becoming shortened and rounded with maturity, the anterolateral margins broadly curving to the front and the anterior margin short and truncate. Measurements of several specimens from various horizons and localities are as follows: length 28.1 mm., 30.7 mm. and 21.1 mm.; width 37.6 mm., 43.6 mm. and 35.3 mm.; thickness 21.8 mm., 27.7 mm. and 21.5 mm.; width along the hinge line 33.7 mm., 32.6 mm. and 33.5 mm. A large pedicle valve is 50.3 mm. long and 69.3 mm. wide.

Pedicle valve more convex than the brachial, highest in the umbonal region, arching strongly and regularly from beak to front, with increasing curvature near the beak, more convex transversely, the surface sloping abruptly from the umbo to the lateral margins. Sinus beginning at the beak, widening and deepening to the front margin, broadly concave, a little angular at the bottom in the umbonal region, less angular and even flattened in some specimens an-

teriorly, marked throughout on either side by a distinct narrow furrow. Lateral slopes gently curved from the cardinal margin to the anterolateral margins and from the sinus to the hinge extremities, each bearing 16 to 20 simple plications, low, flattened or distinctly rounded to subangular and separated by furrows, which are rounded at the bottom and about half as wide as the plications. Beak strong, pointed, incurved and extended. Palintrope high, in some examples about half as high as wide, generally curved for the greater part, more or less flat near the hinge line, vertically and horizontally striated, generally catacline but may be apsacline in the more gibbous shells, possessing angular margins, which are nearly straight from the beak to the hinge extremities. Delthyrium large and nearly as wide as high. Internally the delthyrial supporting plates are strong and support between them a short transverse plate, which is concave toward the hinge line.

Brachial valve moderately curved from beak to front, strongly arched transversely, highest at the middle and slightly depressed near the cardinal angles in some specimens. Fold strongly developed, narrow, broadly to highly convex, distinctly limited at the sides by narrow furrows, usually strongly elevated above the remainder of the valve in larger examples, less so in immature specimens, truncated at the front margin by the extension of the pedicle sinus, typically displaying a shallow, indistinct longitudinal depression on the umbonal portion. Lateral slopes evenly and gently curving from the hinge line to the anterolateral margins and sloping strongly from the fold toward the extremities, bearing plications similar in shape to those of the pedicle valve. Umbonal region low and broadly convex. Beak small, a little projecting and slightly incurved. Palintrope low, gently curved, at right angles to the plane of the valve, and divided by a broad low notothyrium. Internal molds show, besides the muscle scars, the presence of a long, low, indistinct median ridge on the roof of the fold, which extends considerably beyond the midlength.

Surface of both valves marked by numerous fine concentric striae and fewer growth lamellae, of which occasional ones are so pronounced as to interrupt the continuity of the plications. Fold, sinus, plications and furrows marked by small radiating costae, which are more or less papillose where the surface is well preserved.

There is a change in external aspect of the shell with the advance of maturity. In the neanic stage the shells are much wider than long, the greatest width is along the hinge line, the cardinal angles are extended a little, the sinus is angular at the bottom, and the area is wide and high, flat, and at right angles to the plane of the valve or a little retrorse. As the ephebic stage advances the length increases more proportionately than the width, the convexity becomes greater, both longitudinally and transversely, the angles become shortened, the hinge line usually no longer equals the greatest width, and the pedicle palintrope becomes more curved apsacline. In the gerontic stage the shell becomes thick, with crowded lamellose growth lines near the front and lateral margins.

The specific position of *S. parryanus* has been questioned by some workers. Owen had illustrated in 1844 as *S. euruteines* an authentic complete example and an internal mold from dolomitic beds on Pine Creek, Muscatine County, Iowa. Later in 1857, Hall described and illustrated *Spirifer capax* using as his type similar examples of internal molds from the same locality. In 1888 Samuel Calvin discussed *Spirifer parryanus* and *S. capax* and stated that they were the same species. The dolomitic beds on Pine Creek from which these internal molds of *Spirifer* came were long in controversy regarding their age—by many they were considered as equivalent to a sandstone of Mississippian age near Burlington. The recognition by Calvin of the fossils in the dolomite on Pine Creek as Devonian occurring in the upper part of the Cedar Valley settled at once the position of the strata in dispute. Since Owen had illustrated a specimen of *S. capax* as *S. euruteines*, and as Calvin had stated that *S. capax* and *S. parryanus* were the same, Schuchert considered *S. parryanus* to be identical with *S. euruteines* Owen.

However study of Hall's type specimen of *S. parryanus* and of other examples collected in the field shows that, while similar in many respects, these species are distinct. Pro-

portionately *S. parryanus* has a longer, narrower, and thicker shell. Its fold is higher, more strongly convex, and narrower. The sinus is deeper, narrower, more strongly concave at the bottom, and more distinctly defined at the sides. The hinge line is generally less than the greatest width, with the angles seldom or but little extended and usually more or less rounded. The pedicle palintrope of *S. parryanus* is lower than that of *S. euruteines* and is curved throughout. The beak is strongly incurved, and the umbo more arched. The transverse arcuity of the brachial valve is strongly interrupted by the fold and scarcely at all in *S. euruteines*. The plications generally are a little higher, more convex, and separated by more distinct, wider furrows, Differences are apparent in Hall's original illustration of *S. parryanus*, which displays the long, narrow shell, the shortened hinge line, and narrow, highly convex fold. Hall also mentions the subglobose shell, rounded cardinal extremities, and the "prominent, rounded, much elevated fold."

Occurrence.—Cedar Valley limestone, *bellula* zone at Buffalo and Littleton, upper *Pantamerella* zone at Brandon.

Types.—Holotype, American Museum of Natural History, no. 5672/1. Hypotypes S.U.I. nos. 6–283, 6–260; M.A.S. nos. 65, 75, 77, 101, 112, 232.

Spirifer (Spinocyrtia) capax Hall
Plate 67, figures 10–15

Spirifer euruteines (part) Owen, 1852, Geology Wisconsin, Iowa and Minnesota, pl. 3, figs. 2 and 2a.
Spirifer capax Hall, 1858, Geol. Survey Iowa, vol. 1, pt. 2, p. 520, pl. 7, figs. 7a–d.
Spirifer capax, Hall, 1883, New York State Geologist Ann. Rept. 2, pl. 52, figs. 15–17.
Spirifer capax, Calvin, 1888, Iowa Univ. Lab. Nat. History Bull. 1, p. 19 et seq. (united with *S. parryanus* Hall).
Spirifer capax, Hall and Clark, 1893, New York Geol. Survey Paleontology, vol. 8, pt. 2, pl. 22, figs. 15, 16.

Shell medium-sized to large, wider than long, strongly biconvex, subquadrate to semielliptical in outline, with broadly rounded anterolateral margins, truncate front margin, and generally nonextended angles; typically the greatest breadth is in front of the hinge line, especially in gerontic shells. Two internal molds similar to the type in preservation measure 29.6 mm. and 33.4 mm. in length, 43.2 mm. and 44.3 mm. in width and 28 mm. and 32.5 mm. in thickness. Two small but complete individuals measure 24.5 mm. and 29.4 mm. in length, 32.6 mm. and 45.8 mm. in width, and 22.8 mm. and 26.8 mm. in thickness.

Pedicle valve more convex than the brachial, highest in the umbonal region, moderately and regularly arched from beak to front, strongly arcuate transversely. Sinus well developed, originating at the beak, rounded or flattened at the bottom, displaying a shallow groove along each side and in some cases centrally, continued at the front to form a broad lingual extension. Lateral slopes strongly curved from back to front and from the borders of the sinus to the angles, bearing 12–15 strong simple plications, which are low, broadly convex, and separated by linear furrows. Umbonal region strongly elevated. Beak pointed, acute, extended and but slightly curved and occasionally a little twisted. Palintrope high, generally apsacline, occasionally nearly catacline, slightly curved, more so beneath the beak, strongly marked by vertical grooves and weakly by horizontal lines. Delthyrium high, open to the apex, nearly as wide as high at the base. Internally the delthyrial plate is short, flat and concave toward the hinge line. Delthyrial supporting plates thin, extending forward along the floor of the valve about one-third the distance to the front margin. Muscle area reaching nearly to the midline. Most internal molds show that a low median septum extended nearly to the midpoint; it appears to have been variably developed, as some molds show it but faintly.

Brachial valve less convex than the pedicle, arching with moderate rapidity from the front margin and more strongly over the umbo, highest at or near the midpoint, moderately arched transversely. Fold originating at the beak, strongly and broadly convex, generally well elevated above the remainder of the valve, shortened at the front by the opposite sinus. Slope descending rapidly from the fold to the lateral margins, in some specimens slightly concave near the angles, bearing plications similar to those of the pedicle valve. Umbo moderately convex; beak small, slightly projecting,

and incurved. Palintrope low, a little curved, divided by the low broad notothyrium, and situated in the plane of the valve. Internally many examples of internal molds show a median groove extending from the beak forward beyond the midpoint. The median septum is low, variably developed, and scarcely visible in some examples.

Specimens retaining the shell well preserved show that the surface of both valves is marked by numerous fine radiating costae, which number six to eight on each plication. Exceptionally well preserved specimens indicate that the radial costae bear numerous minute papillae as seen in other members of the group. Growth lines are numerous, occasionally laminose and crowded near the front of the valves. Interplicational areas generally lack radial costae but display fine crowded looping growth striae.

An example of this species, an internal mold from Pine Creek, Iowa, was figured by Owen in 1852 as *Spirifer euruteines*. Later Hall, thinking that the shelled example of *S. euruteines* Owen was from the Falls of the Ohio, decided that internal molds from Pine Creek were representative of a different species. He therefore described these molds as *Spirifer capax*. Calvin, studying the "sandstone" at Pine Creek, then erroneously correlated with the Kinderhook, decided that *Spirifer capax* examples were the internal molds of *Spirifer parryanus* previously described. It may be noted here that Calvin included in his *Spirifer parryanus*, good examples of *Spirifer euruteines* Owen. Schuchert, studying Owen's types examples in the National Museum, noted that Owen's internal mold of *S. euruteines* and Hall's internal molds of *S. capax* were the same and he, following Calvin, placed *Spirifer capax* and *Spirifer parryanus* in synonymy with *Spirifer euruteines* Owen. The present writer, after studying numerous examples of all three forms and having collected them in the type areas and strata, has concluded that all are distinct species and has so described them in this paper.

Spirifer capax in many respects is near *S. parryanus* and apparently descended from it. Several features serve to separate them. *Spirifer capax* has a less strongly sinuate anterior commissure, a proportionately longer hinge line and angles less rounded and a little more extended. The main difference, readily apparent in the internal molds, is in the form of the pedicle palintrope; that of *Spirifer capax* is much higher, more triangular and only slightly curved.

Spirifer capax is proportionately longer and narrower than *Spirifer euruteines*, has a considerably higher, narrower and more strongly convex fold, a generally higher and less curved pedicle palintrope, and strongly rounded plications instead of flat.

The examples of *Spirifer capax* at hand are all peculiarly preserved. In the southeast part of the Cedar Valley area of Iowa, as in the type locality at Pine Creek, the fossils are all internal molds of dolomite. In the north-central region, as near Brandon, the brachiopods are generally silicified, with the internal molds having a porcellanous appearance. The silicification process produced variable results. Some examples have the shell and internal mold completely silicified. Another has the internal mold and outer portion of the shell of silica while the inner portion of the shell is calcium carbonate. Still another from the same beds has the external part of the shell and the internal mold of calcium carbonate while the external surface of the internal mold is of silica. These silicified forms of the northern area generally average smaller than the examples from the type region, but in other respects they are similar, and several examples approach the dolomitic internal molds in size. Both types of this brachiopod are from the same horizon in the formation, and their differences are probably explained by their having lived in different marine facies and having suffered variable vicissitudes since burial.

Occurrence.—Cedar Valley limestone in beds immediately above the *waterlooensis* zone at Pine Creek in Muscatine County, Mid River in Johnson County and various localities near Brandon, Iowa.

Types.—The holotype is 4649/2 in the American Museum of Natural History; hypotypes are M.A.S. 75, 77, 140 and 1421.

SPIRIFER (SPINOCYRTIA) BRANDONENSIS Stainbrook, n. sp.

Plate 65, figures 6–9, 11, 12

Shell large, strongly biconvex, much wider than long, widest along the hinge line,

subelliptical in outline, with extended cardinal angles, which become proportionately shorter in maturer specimens, anterolateral margins strongly to gently curved, the front margin incised. Dimensions of several specimens are as follows: length 25 mm., 23.7 mm. and 33.9 mm. (incomplete); width 43.1 mm., 43.7 mm. and 55.1 mm.; thickness 33.9 mm., 55.1 mm. and 27.7 mm. An immature specimen is 17.3 mm. long, 29.8 mm. in width (incomplete) and 15.3 mm. thick. Other specimens indicate that still larger sizes may be attained.

Pedicle valve regularly arched, with moderate curvature from the beak to front along the bottom of the sinus, most convex in the umbonal region, strongly arched transversely in the middle, and depressed toward the angles. Sinus beginning at the beak, widening and deepening toward the front, the sides nearly flat and meeting in a sharp angle along the midline, distinctly defined at the margins by a strong plication, continued at the bottom anteriorly to form a sharp V-shaped linguiform extension. Lateral slopes moderately curved from the hinge line to the front and sloping rapidly from the borders of the sinus toward the hinge extremities, concave toward the angles, the cardinal margins being distinct and shelflike at the extremities; marked by 15–18 simple plications, which are strong, broad, rounded, separated by narrow furrows, and decreasing in size toward the angles. Beak prominent, pointed, strongly projected beyond the hinge line, incurved. Palintrope moderately high, gently curved or flat in the lower portion, strongly curved beneath the beak, horizontally and vertically striated, with the lateral margins angular and sloping with moderate rapidity a short way from the beak and then continuing subparallel with the hinge line to the extremities. Delthyrium large, higher than wide. Internally there are short stout delthyrial supporting plates and a short transverse plate, which is concave anteriorly. A low median septum extends to or beyond the midpoint.

Brachial valve about as convex as the pedicle, arching strongly along the midline over the umbonal region and gently to the front margin, most convex at the midpoint, arched transversely in the middle and depressed toward the angles. Fold originating at the beak, distinctly set off from the slopes by deep furrows, not distinctly elevated above the remainder of the valve, broadly convex; marked mesially by a narrow, moderately deep rounded sinus, which has its origin on the beak and extends forward the full length of the valve in some specimens or becomes faint or obsolete a short distance posterior to the margin in others. Lateral slopes convex, moderately curved from the hinge line to the lateral margins, sloping rapidly from the fold toward the cardinal extremities, depressed anterior to the angles, and bearing plications similar to those on the pedicle slopes. Beak large, blunt, projecting and incurved over the hinge line. Palintrope low, of the same height throughout, slightly concave, orthocline, and divided by a broad low notothyrium. Internally the sockets are narrow and shallow, the socket plates stout and divergent, and the cardinal process gently convex and vertically striated. A median septum is variably developed in different individuals.

Fold, sinus and plications marked by numerous fine radiating costae, which have spinose papillae throughout their extent. Growth lines fine, numerous, more abundant near the margins, occasionally pronounced.

The external aspect of the species varies considerably with the stage of development. In the neanic stage the shell is greatly extended along the hinge line, the length is less than half the width, the area but little curved, the sinus on the fold extends to the front margin, and the anterolateral margins are more or less straight and approach the front margin at low angles. In the later stages the length increases more in proportion to the width, the angles are less acute and extended, the area becomes strongly curved, and the mesial sinus on the fold may become obsolete near the front.

The distinctly angular sinus, the fold with a sinus, the low rounded plications, and the distinct shape and large size readily distinguish this form from any other *Spirifer* in the Cedar Valley. *Spirifer brandonensis* is similar to *Spirifer milwaukeensis* Cleland in many respects but differs in that the angles in the adult forms are more extended, the cardinal area of the pedicle valve maintains the same height nearly to the extremities,

the mesial sinus on the brachial fold is more pronounced, deeper and more extended toward the front, and the plications are lower and broader. *S. milwaukeensis* is not at all like *Spirifer euruteines* and cannot be considered a variety of that form.

Occurrence.—Cedar Valley limestone in the basal bed of the *waterlooensis* zone at Brandon, Littleton, Vinton and Randalia, Iowa.

Types.—Holotype M.A.S. 121; paratypes M.A.S. 343, 344, 345 and S.U.I. 6–444, 6–291, 6–300, and 6–293.

Genus Eosyringothyris Stainbrook, n. gen.

The second group of spiriferoids are of medium size, and although generally uncommon, are present in most zones of the Cedar Valley. The species are characterized by their high pedicle palintropes and peculiar textillated ornamentation. In other features as well they resemble representatives of the Mississippian genus *Syringothyris* but differ from that in the shape of the delthyrial plate and in the impunctate nature of the shell. From *Spirifer* and *Spinocyrtia* these shells display such important differences that a new genus is here erected for them.

Shells spiriferoid in shape, of medium size or larger, unequally biconvex, generally wider than long. Pedicle valve highly convex, subpyramidal, highest at or near the beak, the surface sloping abruptly to the lateral and anterior margins. Sinus extending from the beak to the front margin, gently concave at the bottom, without plications and sharply defined at the sides. Lateral slopes gently curved from the beak to the anterolateral margins and from the cardinal margin anteriorly, bearing moderately strong, narrow, subangular, simple plications, of which only a few reach the beak. Palintrope high, triangular, flat or gently concave, with the apical angle varying from 85° to 110°, varying from strongly procline to apsacline, divided into three divisions by distinct lines running from the beak to points midway between the extremities and the sides of the delthyrium; the two outer areas are horizontally striated and papillated. The inner area is horizontally and vertically striated but is not papillose. Delthyrium nearly three times as high as wide, open, and with grooves along its borders. Internally the delthyrial supporting plates are strongly developed; they rest on the floor of the valve, and their extremities are extended anteriorly some distance on either side of the muscle scars. Transverse delthyrial plate convex or flat above, concave below, extending inward and forward almost halfway to the hinge line, ending in a short, sharp median spine. On the inner surface the plate is thickened posteriorly and deeply excavated anteriorly a millimeter or so from the end. There are no ridges comparable to those of *Spirifer marcyi*. A slight median septum is present in some species.

Brachial valve gently convex. Fold broad, low, convex, not plicate, sometimes showing an incipient median sinus. Lateral slopes gently curved from the hinge line anteriorly and from the sinus to the angles. Plications similar to those of the opposite valve. Palintrope low and orthocline, divided by a broad low notothyrium. Internally the cardinal process is subquadrate, broadly convex, and vertically grooved. The sockets deep, narrow and straight. The crural plates are stout, diverge from the process at angles of 45°. The posterior adductor scars are short and arcuate. The posterior adductors long, narrow, extended a little beyond the midpoint, and separated by a stout, low median ridge.

The entire exterior of the shell, with the exception of the triangular area enclosing the delthyrium, is strongly papillose. The papillae generally have no regular arrangement and are sometimes elongate and almost spinose. In the sinus and on the fold many of the papillae are aligned along the edges of the growth lines and in rows radiating from the beaks. Some of the papillae appear to be hollow on the end, if so, the cavity does not penetrate the shell proper. The shell substance is fibrous and impunctate; search with hand lens and compound microscope on surface and thin sections reveals no punctae.

The genotype is *Spirifer asper* Hall. *Syringothyris occidentalis* (Swallow) and additional species described in this paper are also placed in the genus.

Members of *Eosyringothyris* are similar to *Syringothyris* in shape, in the divisions of

the palintrope of the pedicle valve, and in the textillated exterior. They differ from that genus in the shape of the delthyrial plate, in the lack of a syrinx, and in the impunctate nature of the shell substance. *Eosyringothyris* is distinguished from *Spirifer* by the delthyrial plate, which ends in a spine, in the papillose nonradially costate exterior, in the division of the pedicle palintrope in three regions, and in the nonplicate fold and sinus. These same characters will separate *Eosyringothyris* from *Platyrachella*. From *Spinocyrtia* the spinose delthyrial plane and the lack of radial costae distinguish this proposed genus.

Eosyringothyris appears to be ancestral to *Syringothyris*, requiring the development of a true syrinx from the spinose delthyrial plate and the acquisition of punctae. The resemblance may, however be due to convergent evolution. In other features also this genus seems more probably the ancestral stock of *Syringothyris* rather than *Platyrachella* as suggested by Fenton and Fenton (1924, p. 159). *Syringothyris* never has a plicated pedicle sinus.

EOSYRINGOTHYRIS ASPERA (Hall)
Plate 68, figures 17–27; text figures 1–3

Spirifer aspera HALL, 1858, Geol. Survey Iowa, vol. 1, pt. 2, pp. 508–509, pl. 4, fig. 7.
Spirifer asper, HALL and CLARKE, 1894, New York Geol. Survey Paleontology, vol. 8, pt. 2, pp. 29, 31, 32, 39, pl. 25, figs. 20–25.
Spirifer asper, SCHUCHERT, 1897, U. S. Geol. Survey. Bull. 87, p. 382. (Not *Spirifer asper* Branson, 1924, Devonian of Missouri, p. 100, pl. 19, figs. 19–23; pl. 23, fig. 4.)

Shell of medium size, very unequally biconvex, wider than long, with the greatest width along the hinge line, semielliptical in outline, with the angles greatly extended. Dimensions of three hypotypes are as follows: length 17.1 mm., 15.3 mm., and 17.5 mm.; width 30.7 mm., 30.1 mm. and 40.1 mm.; thickness 12 mm., 9.7 mm., and 21.3 mm.; apical angle 110°, 110° and 117°.

Pedicle valve more convex than the brachial, subpyramidal in shape, highest at the beak, the surface dropping abruptly to the margins. Sinus originating at the beak, widening and deepening toward the front, rounded at the bottom, projecting anteriorly as a short rounded lingual extension, and sharply distinct along the upper margins. Lateral slopes gently convex or slightly concave, flat or gently curving from the cardinal margins anteriorly and from the sinus to the angles. On each slope are about 20 narrow simple plications, gently angular at their summits, separated by narrow furrows, and gradually decreasing in size toward the extremities. Beak sharp, scarcely incurving, situated usually near the midpoint, and forming the apex of the valve. Palintrope high, usually about twice as wide as high, flat or gently concave, usually strongly procline but approaching catacline in maturer stages; divided into three regions of which the two outer ones are horizontally striated and papillose but not so strongly as the slopes; the inner region is both horizontally and vertically striated. Delthyrial supporting plates strong, their upper extremities extending all along the borders of the delthyrium and ending anteriorly in two stout teeth, and their lower extremities reaching the floor of the valve, where they are divergent and extend only a short way forward. Transverse delthyrial plate strong, extending forward and downward to a point near the middle of the delthyrium, subangular above, concave below, and ending in a short, sharp spine.

Brachial valve gently arched from beak to front along the crest of the fold, with the curvature strongest over the umbo, gently

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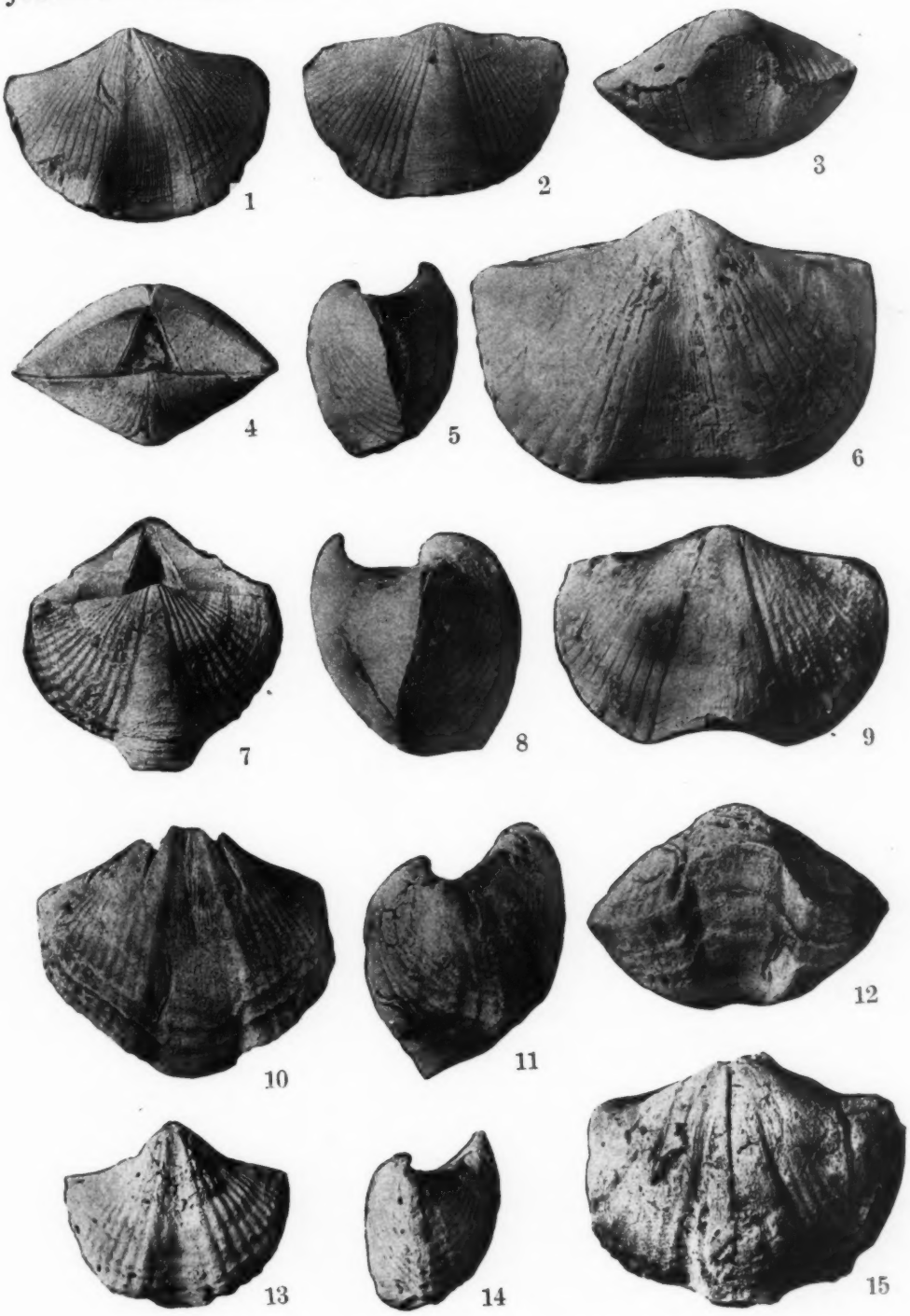
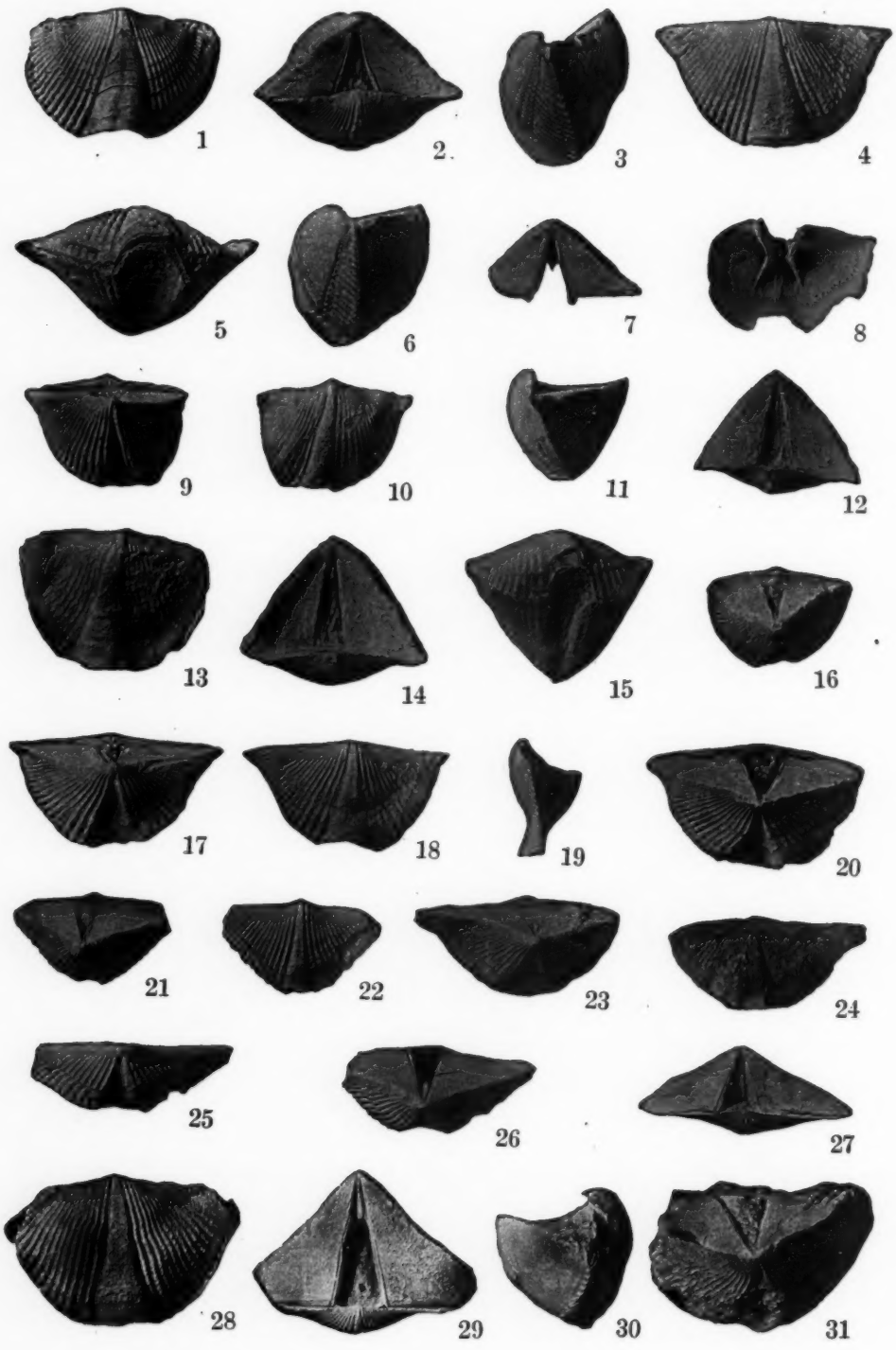
EXPLANATION OF PLATE 67

FIGS. *1–6, 8, 9—Spirifer* (*Spinocyrtia*) *euruteines* Owen. *1–5*, Pedicle, brachial, anterior, posterior, and lateral view of a hypotype (S.U.I. 6-255A), which was compared with the type, Muscatine county, Iowa. *6*, Pedicle view of a large hypotype (S.U.I. 6-255A), Atalissa, Iowa. *8–9*, Lateral and brachial views of a hypotype (M.A.S. 1376), Buffalo, Iowa. (p. 423)
10–15—Spirifer (*Spinocyrtia*) *capax* Hall. *10–12*, Pedicle, lateral and anterior views of an internal mold, compared with and from the same locality as the type (M.A.S. 75), Pine Creek, Muscatine county, Iowa. *13–14*, Pedicle and lateral views of a small specimen from the *waterlooensis* zone at Brandon, Iowa. *15*, Brachial view of an internal mold showing evidence of a well-developed septum (M.A.S. 1421), Pine Creek, Iowa. (p. 428)



Stainbrook, Devonian Brachiopoda



Stainbrook, Devonian Brachiopoda

arched transversely and highest at the middle. Fold extending from the front margin to the beak, broadly convex, wider and higher toward the front, a little elevated above the remainder of the valve, flattened a little and showing an incipient mesial sinus, which is better developed in the umbonal region. Slopes gently curved from back to front and from the fold to the angles, marked by plications similar to those on the pedicle slopes.

Entire surface of the shell except for the central region of the pedicle palintrope is papillose. Concentric growth lines are not uncommon, sometimes pronounced, and often crowded near the front and lateral margins.

In the neanic stage the pedicle valve is very short from beak to front; the beak is but little elevated and is nearer the front margin than the hinge line; the palintrope is gently concave, greatly procline, and in the lower portion may be nearly parallel with the brachial valve, the angles are greatly and acutely extended, and the brachial valve is depressed and very gently convex. In the ephebic stage the length of the shell increases, the pedicle beak becomes more elevated, and the angles abruptly extended. In the gerontic stage the shell is thick, the angles sometimes but little extended, the pedicle valve is subpyramidal, and the palintrope more nearly at right angles to the plane of the valve. The apical angle appears to remain constant throughout.

Study of the type specimen in the American Museum of Natural History shows that the species should be limited to the form from the *bellula* zone of the Cedar Valley. The larger form, occurring higher in the section and generally regarded as typical *Spirifer asper*, is a different species. The form described by Branson as *Spirifer asper* is not conspecific and appears to be *Syringothyris occidentalis* (Swallow). Fenton and Fenton (1924, p. 159) state that *Spirifer asper* belongs to *Platyrachella* Fenton and Fenton. This species differs considerably from the genotype, *Spirifer macbridei*, in the form of the transverse delthyrial plate in the divisions of the pedicle palintrope, in ornamentation, and in the lack of a plication in the pedicle sinus.

Occurrence.—Cedar Valley limestone in the *bellula* zone at Iowa City (type locality and horizon), at Linder's Boathouse, Solon, and elsewhere in Johnson county; at Buffalo; Davenport, and Toddville, Iowa.

Types.—Holotype 6280/1 A.M.N.H.; hypotypes S.U.I. 6-269, 6-271, 6-279 and 6-543; M.A.S. 130, 142, 149, 284, and 1422.

EOSYRINGOTHYRIS THOMASI Stainbrook, n. sp.

Plate 68, figures 1–8; text figure 11

Syringothyris occidentalis (Swallow) (part). BRANSON, 1924, Geology of Missouri, p. 103, pl. 21, figs. 1–3, pl. 23, fig. 1; text fig. 9, figs. 11–14 (not pl. 20, figs. 3–5).

Shell medium-sized to large, strongly and unequally biconvex, wider than long, with the greatest width along the hinge line, semielliptical in outline, the lateral margins broadly rounded, the front margin short and truncated, and the angles abruptly but not

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EXPLANATION OF PLATE 68

FIGS. *1–8—Eosyringothyris thomasi* Stainbrook, n. sp. *1–3*, Brachial, posterior, and lateral views of the holotype (S.U.I. 6-218A). *4–6*, Brachial, anterior and lateral views of a paratype (S.U.I. 6-218). *7, 8*, Posterior and internal views of a pedicle valve (S.U.I. 6-218). All from Scott county, Iowa. (p. 433)

9–16—Eosyringothyris triangularis Stainbrook, n. sp. *9–12*, Pedicle, brachial, lateral, and posterior views of the holotype (S.U.I. 6-264). *13*, Brachial view of the largest paratype (S.U.I. 6-276). *14, 15*, Posterior and anterior views of another paratype (S.U.I. 6-264). All from Littleton, Iowa. *16*, Posterior view of a paratype (M.A.S. 1450), Brandon, Iowa. (p. 435)

17–27—Eosyringothyris aspera (Hall). *17–19*, Pedicle, brachial, and laterial views of a hypotype *20*, Pedicle view of another. Both (S.U.I. 6-269) from Davenport, Iowa. *21, 22*, Pedicle and brachial views of a hypotype. *23, 24*, Pedicle and brachial views of a wider form. *25, 26*, Pedicle and posterior views of a young specimen. *27*, Cardinal view of another. All from the *bellula* zone at Iowa City, Iowa. (p. 432)

28–31—Eosyringothyris calvini Stainbrook, n. sp. *28, 29*, Brachial and posterior views of the holotype (M.A.S. 1397), Waterloo, Iowa. *30*, Lateral view of a paratype (M.A.S. 340), Brandon, Iowa. *31*, Pedicle view of a paratype (M.A.S. 130), Littleton, Iowa. (p. 436)

greatly extended and sometimes rounded. The dimensions of three average specimens are: length of the brachial valve 18.1 mm., 19.1 mm. and 19.3 mm.; thickness 19.6 mm., 20.6 mm. and 18.5 mm.; apical angle 102°, 100° and 100°.

Pedicle valve subpyramidal, highest at the beak or a little anterior, the surface sloping rapidly to the anterior and lateral margins, moderately arched along the bottom of the sinus from back to front, in some specimens very gently so. Sinus widening and deepening from the beak to the front margin, with distinct lateral margins formed by plications slightly larger than the remainder, broadly concave or flattened along the bottom, extended a little at the front. Lateral slopes gently curved to the lateral margins, slightly concave in front of the extremities, marked by narrow, simple plications, rounded along their summits, decreasing in size toward the angles, numbering about 20 on each slope, and separated by narrow furrows. Beak highly elevated, sharply pointed, scarcely incurving, sometimes slightly distorted. Palintrope high, broadly triangular, with the lateral margins sharply angular and sloping evenly from the beak to the extremities, flat or very gently concave, divided into three regions as in *Eosyringothyris aspera*, generally apsacline, especially in older examples, sometimes catacline, and with an apical angle averaging about 100°. Delthyrium narrowly triangular, the height more than twice the width at the base, with a groove along the border on either side. Internally the delthyrial supporting plates are strongly developed and continue to the floor of the valve, becoming divergent and extending a short way anteriorly. Between and connecting them posteriorly is a narrow transverse delthyrial plate, convex above, concave below, projecting at the front in a sharp spine, and extending forward and downward less than half the height of the delthyrium. A short obsolescent median septum appears between the muscle scars.

Brachial valve moderately convex, regularly arched along the crest of the fold, but with the curvature a little stronger over the umbo, more strongly arched transversely in the central portion, highest near the middle. Fold extending from beak to front, moderately elevated above the slopes, bordered at the sides by furrows, which are not noticeably larger than the others, broadly depressed along the summit and showing an incipient median sinus. Slopes gently curved from the hinge line anteriorly, sloping with moderate rapidity from the fold toward the angles, and becoming concave in front of the extremities, bearing plications similar to those of the pedicle valve. Beak curving, a little extended. Palintrope low, divided by a broad low notothyrium, and slightly apsacline.

Surface of the fold, sinus, and plications marked by numerous granules with no particular arrangement. Concentric growth lines numerous, sometimes a little lamellose, often crowded near the front and occasionally prominent. No punctae were observed. The external and internal features place this species in the genus *Eosyringothyris*. It shows little variation in passing from one growth stage to another.

Eosyringothyris thomasi is a larger, thicker, and more robust form than *Eosyringothyris aspera*, is longer in proportion to width, especially in the neanic stage, has the beak of the pedicle valve more posteriorly situated, has a higher pedicle palintrope which has an apical angle of 100° instead of 110°, and which is rarely procline. From *Eosyringothyris triangularis* this species may be distinguished by its larger size, its lower palintrope in proportion to width, and by its more obtuse apical angle, 100° instead of 85°.

Branson has figured large examples of an *Eosyringothyris* as *Syringothyris occidentalis* which apparently are representatives of *E. thomasi*. Swallow's description of *S. occidentalis* indicates a form in which the height of the pedicle palintrope is not much less than its width at the base. This character seems to be more applicable to a smaller species occurring in the Callaway limestone with *Cyrtina missouriensis* (Swallow). This smaller species is described in this paper as *Eosyringothyris occidentalis*.

Occurrence.—Cedar Valley limestone in the *Stropheodonta parva* zonule of the upper part of the *Pentamerella* zone at Buffalo, Linwood, Davenport and Moscow. Apparently confined to the southeast portion of the Devonian area of Iowa. It occurs in the

same zone at Annada, and in the Callaway linestone in Callaway and Boone Counties, Mo.

Types.—Holotype S.U.I. 6-281A; paratypes are S.U.I. 6-275, 6-277, 6-280, 6-281 and 6-205, and M.A.S. 164, 518, 201, 355 and 1423.

EOSYRINGOTHYRIS TRIANGULARIS
Stainbrook, n. sp.
Plate 68, figures 9–16

Shell of medium size, subpyramidal in shape, wider than long, broadest along the hinge line, semiovate in outline, with the angles abruptly but shortly extended, the lateral margins long and nearly at right angles to the hinge line, and broadly curved along the front margin. Dimensions of the holotype and of a paratype are: length 15.9 mm. and 13.4 mm.; width 23.3 mm. and 20.7 mm.; thickness 17.5 mm. and 13.7 mm.; height of area 13.4 mm. and 10.7 mm.; apical angle 85° and 90°. A larger but distorted specimen is 13.7 mm. long, 26.3 mm. wide, and 21.1 mm. thick. The area is 15.6 mm. high and has an apical angle of 85°.

Pedicle valve much more convex than the brachial, subpyramidal in shape, highest at the beak, the surface sloping abruptly thence to the margins, and slightly arched or straight along the bottom of the sinus from the beak anteriorly. Sinus expanding and deepening gradually from the beak to the front margin, flattened or gently concave at the bottom, the sides sloping rapidly from the bordering plications, the anterior portion forming a short rounded linguiform extension. Lateral slopes nearly flat, gently curved from the beak to the anterolateral margins and from the hinge line anteriorly. Plications numbering 13–18 on each slope, low, simple, narrow, rounded, separated by linear furrows, and decreasing in size toward the angles, the last four or five being minute. Beak sharply pointed, forming the highest part of the valve, situated near the middle, not incurved. Palintrope high, nearly an equilateral triangle in some examples, with the lateral margins sharp and nearly straight from the beak to the extremities, flat or very gently concave, always procline, and never making a right angle with the plane of the valve; divided into three regions, the two lateral ones being horizontally striated and granulose, and the middle one horizontally and vertically striated; apical angle varying from 80° to 90° but in the majority of specimens is about 85°. Delthyrium three times as high as wide at the base, bordered by a furrow along each margin. Internally the delthyrial supporting plates are strongly developed and slightly divergent from each other. The transverse delthyrial plate, convex above and concave below, extends anteriorly almost to the middle of the delthyrium and ends there as a sharp spine.

Brachial valve gently convex, evenly arched from beak to front and from side to side, highest near the midpoint. Fold narrow, depressed convex, the sides dropping abruptly to the furrow on either side, elevated a little above the remainder of the valve, and shortened at the front by the extension of the pedicle sinus. Slopes gently curving, marked by plications similar to those on the opposite slopes. Beak long, a little projecting and incurving. Palintrope low, divided by a low notothyrium, a little apsacline.

Surface of the shell except for the central portion of the cardinal area of the pedicle valve marked by numerous granulose papillae; those on the palintrope are not as strongly developed as those on the slopes or fold. Growth lines numerous, occasionally strongly developed, and often crowded near the margin.

In the earlier stages of growth the shell has gradually extended cardinal angles, and these become more abruptly extended with maturity. In other characteristics the shell changes but little in external appearance. The granulose exterior, the high, tripartite area, and the delthyrial plate with a spine show that this species belongs to *Eosyringothyris*. *Eosyringothyris triangularis* is thicker, longer, and narrower, proportionately, than *Eosyringothyris aspera*, has proportionately a more convex pedicle valve, a higher narrower area, and an apical angle of about 85° and never more than 90°; the apical angle of the latter is about 110° and is rarely less.

Occurrence.—Cedar Valley limestone in the lower portion of the *waterlooensis* zone at Littleton and Brandon, Iowa.

Types.—The holotype is S.U.I. 6-264A;

paratypes are S.U.I. nos. 6-264, 6-276 and M.A.S. 130.

EOSYRINGOTHYRIS CALVINI Stainbrook, n. sp.
Plate 68, figures 28–31

Shell above medium size, very unequally biconvex, semielliptical in outline, with extended angles, broadly rounded anterolateral margins, which are somewhat concave in front of the extremities, and short truncate front margin. Wider than long, with the greatest width along the hinge line. In adults the pedicle valve, its palintrope, and the brachial valve in longitudinal section nearly form an equilateral triangle. Measurements of the holotype and of a paratype are: length of brachial valve 21.1 mm. and 20.8 mm.; width 38.4 mm. (partly restored) and 32.1 mm. (partly restored); thickness 23 mm. and 21.1 mm. A small paratype is 10.4 mm. long, 21.3 mm. wide and 6.5 mm. thick.

Pedicle much more convex than the brachial, subpyramidal in shape, highest at the beak, the surface sloping thence abruptly to the margins and hinge line. Along the midline the valve is but little arched. Sinus originating at the beak, shallow, broadly convex or flattened at the bottom, extended in front to form a short lingual extension. Slopes nearly flat, gently arching from the borders of the sinus and a little concave toward the angles, where a shelflike extension may be developed. Plications low, narrow, simple, rounded at the summit, separated by much narrower furrows and numbering about 18 on each slope. Beak strong, acute, not incurved, occasionally twisted slightly, situated near the midpoint, and forming the highest part of the valve. Palintrope large, high, generally flat in mature examples, slightly concave in young specimens, and having an apical angle of 107° to 110°; it is divided into three areas as in *E. aspera* and is strongly procline, greatly so in immature examples. In only one specimen at hand is the palintrope catacline. Delthyrium more than twice as high as its width at the base in gerontic forms. Internally the delthyrial supporting plates are strong and well developed. The transverse plate extends anteriorly about one-third the distance to the hinge line, is strongly convex outwardly, concave below, and terminates in an acute spine.

Brachial valve gently convex, highest at the midpoint, more strongly arching over the umbo. Fold narrow, low, distinctly elevated above the remainder of the valve, broadly convex to nearly flat along the summit, and in some examples showing a faint trace of a mesial sinus. Slopes arching gently from the hinge line to the front, descending slowly from the borders of the fold, and slightly concave toward the angles. Plications as in the pedicle valve. Beak small, a little projecting, and incurved. Palintrope low, flat for the most part, curved beneath the beak, divided by a broad low notothyrium, and showing some evidence of division into areas as in the opposite valve. Internally the cardinal process is elliptical and vertically striated. The dental sockets are deep, narrow, straight, and open anteriorly. The crural plates are broad anteriorly and a little concave above. Muscle scars faint, and the median ridge but obscurely developed.

The entire surface of the shell with the exception of the inner area of the palintrope is marked by abundant papillae as in other members of the genus.

Eosyringothyris calvini is probably the shell mentioned by Hall (1894) as an undescribed form from Littleton, Iowa, in the possession of Dr. Calvin. In the immature stages it resembles *Eosyringothyris aspera* in shape and in the proclinity of the pedicle palintrope. Also in the ephebic and gerontic stages *E. calvini* has a pedicle palintrope with a somewhat smaller apical angle. *E. calvini* is longer proportionately, the brachial valve is differently shaped and has shelflike extensions on the pedicle valve in front of the angles.

E. calvini is not as robust as *E. thomasi*, has a less convex brachial valve, more extended angles, a narrower fold and sinus, and a proportionately higher and larger pedicle palintrope, which is a little apsacline instead of strongly procline.

Occurrence.—Cedar Valley limestone in the upper part of the *waterlooensis* zone at Waterloo, Littleton, Palo and Brandon, Iowa.

Types.—Holotype M.A.S. 1397; paratypes are S.U.I. 6-265 and 6-270, M.A.S. 130, 340 and 1424.

EOSYRINGOTHYRIS OCCIDENTALIS
(Swallow)
Plate 69, figures 1–5

Cyrtia occidentalis SWALLOW, 1860, St. Louis Acad. Sci. Trans., vol. 1, pp. 648–649.
Cyrtina occidentalis, MILLER, 1889, North American Geology and Paleontology, p. 343.
Cyrtina? occidentalis SCHUCHERT, 1897, U. S. Geol. Survey Bull. 87, p. 199.
Spirifer asper BRANSON, 1924, Missouri Bureau Geology and Mines, ser. 2, vol. 17, pl. 19, figs. 19–23.
Syringothyris occidentalis, BRANSON, 1924, idem, pl. 20, figs. 3–5 (not pl. 21, figs. 1–3).

Shell of medium size or smaller, strongly and unequally biconvex, subquadrate in outline, with nearly straight lateral margins and nonextended or slightly rounded angles, wider than long, with the greatest width anterior to the hinge line. Measurements of three hypotypes are: length of the brachial valve 16.5 mm., 19.3 mm. and 14.3 mm.; width 22.8 mm., 24.6 mm. and 20.1 mm.; thickness 17.5 mm., 16.8 mm. and 13.2 mm.; height of pedicle palintrope 11.1 mm., 11.6 mm. and 9.7 mm.

Pedicle valve strongly convex, subpyramidal, highest at the beak, whence the surface descends abruptly and with nearly equal rapidity to the margins. Sinus originating at the beak, shallow, broadly rounded or flattened along the bottom, continued at the front as a short lingual extension. Slopes moderately curved from back to front but gently arched to nearly flat from the beak to the lateral margins. Plications low, simple, narrow, gently convex, numbering 18–22. Beak greatly elevated, pointed, sometimes twisted slightly and a little incurved. Palintrope high, flat or gently concave, generally catacline, but may vary a little backward or forward, width at base to height as 20 to 13; having an apical angle of about 90°, and divided into three regions as in other species. Internally the transverse delthyrial plate extends halfway or more toward the hinge line, is convex, and ends in a short sharp spine.

Brachial valve subquadrate in outline, gently convex, strongly arched over the umbo to the midpoint and slightly thence to the front, moderately and regularly arched transversely. Fold originating at the beak, very low, broad, flat or gently convex, displaying an incipient median sinus. Slopes moderately arched from the hinge line to the front, gently sloping from the fold laterally, a little concave in front of the angles, bearing plications as in the opposite valve. Palintrope low, apparently orthocline. Interior unknown.

Branson has described under this specific name a larger species which we believe is the same as our *E. thomasi*. In the upper part of the Callaway limestone occurs a small species of *Eosyringothyris* which agrees well with Swallow's description. This author mentions the high semiconical ventral valve, the slightly concave area with its base but little longer than the sides, the slightly incurved beak, and the cardinal line which is shorter than the width. These features are characteristic of this smaller form. It occurs with *Cyrtina missouriensis*, which was described at the same time by Swallow and gives further evidence that this small species is his *Cyrtina occidentalis*.

Eosyringothyris occidentalis is smaller, narrower than *E. aspera* (Hall), has a proportionately higher and narrower pedicle palintrope, which is generally catacline instead of strongly procline. The apical angle is 90° instead of 110° and the angles are not extended.

This species is considerable smaller than *E. thomasi* of lower zones of the Cedar Valley and Callaway. It is narrower and longer proportionately, has rounded or nonextended angles, has an apical angle about 20° more acute, a more incurved and twisted beak and a higher, narrower pedicle palintrope proportionately.

Esosyringothyris occidentalis is near *E. triangularis* in size but is shorter in proportion to width and has rounded angles, while those of the latter are acute. Its pedicle palintrope is lower as compared to width, is never procline as is constant in *E. triangularis*, and has an apical angle of 90° compared with 85°. It is easily distinguished from *E. calvini* by its smaller size, nonprocline pedicle palintrope, nonextended angles and different shape.

Occurrence.—Cedar Valley limestone in the *Schizophoria lata* zone at Buffalo, Iowa; Callaway limestone in the *Cyrtina missouriensis* zone on Aux Vasse creek, Callaway County, Mo.; zone C of the Milwaukee formation at Milwaukee, Wis.

Types.—Hypotypes are S.U.I. 6–261 and M.A.S. 283, 356 and 1296.

Genus TYLOTHYRIS North, 1920

The species forming the third group of spiriferoids in the Cedar Valley are generally of medium size or below, have strongly laminose exteriors and plicate fold and sinus. They are more numerous in the basal portion of the formation but occur in all zones. Individually the species are generally common. Of the numerous genera separated from *Spirifer* in recent years they agree most nearly with the genus *Tylothyris* North, which is based on specimens from the Carboniferous limestone. Although our examples are from the Devonian they differ but little in most respects, as may be seen in the following summary of generic characters of our Cedar Valley forms.

Shell of medium size to small, biconvex, spiriferoid in shape, with angles extended to rounded, generally with the greatest width along the hinge line, semielliptical to subquadrate in outline.

Pedicle valve the more convex, gently to strongly curved from beak to front. Sinus originating at the beak, deep, in most cases with a median plication or occasionally flat and not plicate at the bottom. Slopes marked by numerous simple strong subangular plications, separated by narrower furrows, and only a few reaching the beak. Palintrope variable, often high, nearly flat to strongly curved, horizontally and vertically striated; usually the outer portion on either side is horizontally marked only. A strong groove extends from the beak to the hinge line along the immediate margins of the pedicle opening. No deltidium was observed in any of the numerous specimens at hand. Beak pointed, often elevated, incurved in some and not at all in others. Internally the delthyrial supporting plates are strongly developed, concave anteriorly and toward the angles, and extended a short way forward along the floor of the valve. They are also slightly excavated below the margins of the palintrope as is *Spinocyrtia*. Between the delthyrial supporting plates is a transverse structure varying from a callus to a true plate concave anteriorly and extending a short distance forward. A thin erect median septum extends to the midpoint, where it generally attains its greatest height.

Brachial valve generally gently to moderately convex. Fold strong, extending from beak to front, elevated, broadly convex, depressed mesially by a deep sinus in most species, in others the sinus may be obsolete. Slopes marked by plications as in the opposite valve. Internally the cardinal process is subquadrate to semielliptical in outline, broadly convex, and vertically grooved. The sockets are deep, narrow, and laterally directed. A thin slight median septum is variably developed in most species.

Exterior of the valves excepting the palintropes marked by numerous concentric growth laminae. The shell substance is fibrous and impunctate.

Our species differ from the genotype, *Tylothyris laminosa*, in but few details. The mesial septum of the pedicle valve is not as strongly developed and is highest anteriorly. The apical callosity is not as strong in most species, and the apical chambers formed by the union of the callosity with the median septum are very small. Most of our species have a mesial sinus on the fold and a plication in the pedicle sinus, but one species does not and in the others there occur examples in which neither is present. These differences seem to be due to evolutionary trends and probably are not of generic importance.

TYLOTHYRIS BIMESIALIS (Hall)

Plate 69, figures 9–15; text figure 9

Spirifer bimesialis HALL, 1858, Geol. Survey Iowa, vol. 1, pt. 2, p. 507, pl. 4, fig. 6.
Spirifera bimesialis, HALL, 1883, New York State Geologist Ann. Rept. 2, pl. 59, figs. 23–26.
Spirifer bimesialis, HALL and CLARKE, 1895, New York Geol. Survey Paleontology, vol. 8, pt. 2, pp. 17, 36, pl. 34, figs. 23–26.
Spirifer bimesialis, SCHUCHERT, 1897, U. S. Geol. Survey Bull. 87, p. 383.

Shell above medium size, moderately biconvex, semielliptical in outline, with the greatest width along the hinge line, wider than long, sometimes more than three times as wide, with the angles extremely variable, typically greatly extended, sometimes short and abruptly projecting, or more rarely subangular and but little extended. Dimensions of several hypotypes are as follows:

length 10.8 mm., 10.4 mm., 7.2 mm., 10.5 mm., 15.5 mm. and 10 mm.; width 35.1 mm., 30.1 mm., 23.3 mm., 23.3 mm., 24.9 mm. and 26.7 mm.; thickness 9.6 mm., 8.5 mm., 5.7 mm., 10.6 mm., 11.5 mm. and 13.1 mm.

Pedicle valve moderately convex, strongly and regularly arched along the midline from the beak to the anterior margin, strongly convex transversely in the middle portion, depressed toward the angles, and highest a little posterior to the beak. Sinus continuous from the front to the beak, deep, with margins distinct and marked laterally by plications larger than the average, the sides dropping steeply to the bottom, which is occupied in the middle by a single strong plication; the front is slightly extended and truncated by the opposite fold. Lateral slopes moderately curving near the sinus from the cardinal margin to the front, flattened and becoming concave toward the extremities with a shelflike extension along the margin of the palintrope; occupied by 10–18 or more simple, narrow plications, separated by furrows of less width and decreasing in size toward the extremities. Umbonal region convex, projecting and incurving posteriorly. Beak small, pointed, a little incurved and projected beyond the hinge line. Palintrope varying a little in height, generally low, flat in the lower portion, usually strongly curved beneath the beak, situated at right angles to the plane of the valve or posteriorly inclined, its lateral margins sharp and sloping abruptly near the beak then gently to the extremities so as to be parallel to the hinge line for a short way. Delthyrium higher than wide, narrow. Internally there is a short apical callus between the delthyrial supporting plates and a small low mesial septum anterior to it.

Brachial valve less convex than the pedicle, highest at the midpoint, arching with moderate rapidity along the midline with the curvature increasing over the umbo, gently convex transversely, depressed in front of the angles. Fold extending from the beak to the front margin, moderately wide, low, but little elevated above the slopes, distinctly delimited at each side by a narrow furrow, depressed mesially by a sinus, which originates in front of the umbo and deepens to the front margin, giving the fold the appearance of being formed by two large plications. Lateral slopes gently curved from the hinge line to the front margin and from the fold toward the extremities, depressed in front of the angles, displaying a shelflike projection along the hinge line, marked by plications similar to those of the pedicle valve. Umbo not prominent, curved posteriorly. Beak small, blunt, and but little projecting. Palintrope low, of nearly the same height throughout, orthocline, situated at right angles to the opposite area.

The fold, sinus and plications are strongly marked by imbricating growth lamellae. These with the impunctate shell substance, the apical callosity, and the median septum in the pedicle valve place this species in the genus *Tylothyris*.

The species is variable in form and even a small collection appears at first glance to comprise several species. However, a little study will show that the forms intergrade, and a continuous series from the extremely wide to the narrow varieties may be formed. Much of the variation is due to individuals of small size assuming the characteristics of the later stages. In the neanic stage the shells are typically short, nearly three times as wide as long, and with the angles greatly extended and pointed. The ephebic stage is characterized by decreasing width in proportion to length, by proportionately greater thickness, and by a slightly higher, more posteriorly inclined area. The pedicle palintrope also may be disproportionately heightened. Occasional specimens may show a nearly obsolete sinus on the brachial fold, but these examples occur with normal individuals.

Occurrence.—Cedar Valley limestone in the ***independensis*** zone in upper part at Independence, Waverly, Vinton, Solon, Linn Junction, Davenport, and Buffalo. Milwaukee beds at Milwaukee, Wis. It is reported by Clarke from the High Point fauna, but a recent examination of Clarke's specimens in the Schuchert Collection shows that the species does not occur in that fauna.

Types.—The holotype is in the American Museum of Natural History. Hypotypes are S.U.I. 6-450, and M.A.S. 76, 233, 238, 347, and 1425.

TYLOTHYRIS INUTILIS (Hall)
Plate 69, figures 25–28, 30–34;
text figure 8

Spirifer inutilis HALL, 1858, Geology of Iowa, vol. 1, pt. 2, p. 505, pl. 4, fig. 4.

Shell of medium size, strongly and inequally biconvex, transversely subelliptical to subquadrate in outline, wider than long, with the greatest width along the hinge line, which may be straight or a little curved near the extremities, the angles more or less extended, sometimes abruptly so, lateral margins long, gently to abruptly curved toward the front, the anterior margin short and truncate. Dimensions of several specimens are: length 12.6 mm., 12.5 mm., and 10.8 mm.; width 22.6 mm., 20.3 mm., and 17.6 mm.; thickness 11.4 mm., 14.2 mm., and 11.2 mm; height of pedicle palintrope 9.3 mm., 9.6 mm. and 8.7 mm.

Pedicle valve strongly convex, subpyramidal, highest at the beak, the surface sloping abruptly thence to the margins. Sinus extending from beak to front, narrow, deep, bordered laterally by large plications, the sides flat and dropping rapidly to the bottom, occupied centrally by a prominent single angular plication. In some examples the median plication may be faint or absent. Lateral slopes gently curved from the border of the palintrope to the anterolateral margins and from the sinus to the cardinal extremities, depressed in front of the angles with the palintrope margin often projecting into a shelflike extension. Slopes marked by 10-13 strong simple angular plications, separated by narrower furrows and decreasing in size to the extremities. Beak greatly elevated, sharply pointed, slightly or not at all incurved, sometimes a little distorted. Palintrope high, variable, broadly triangular, with sharply distinct lateral margins, which are convex or straight from the beak to the extremities, flat or very gently curved, generally procline, usually strongly so, sometimes nearly procline. Delthyrium high, narrow, and with a groove along each side. Internally there is a short convex transverse delthyrial plate, which is concave anteriorly. Sections of the rostral portion of the pedicle valve disclose the presence of a low, narrow mesial septum between the delthyrial supporting plates.

Brachial valve gently convex, highest near the midpoint, moderately arched from beak to front along the fold, with the cur-

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EXPLANATION OF PLATE 69

FIGS. *1–5—Eosyringothyris occidentalis* (Swallow). *1–3*, Pedicle, brachial, and posterior views of a hypotype (M.A.S. 283), Buffalo, Iowa. *4*, Brachial view of a hypotype (M.A.S. 356), Callaway limestone, Aux Vasse Creek, Mo. *5*, Brachial view of a hypotype (M.A.S. 1296), zone C, Milwaukee limestone, Milwaukee, Wis. (p. 437)

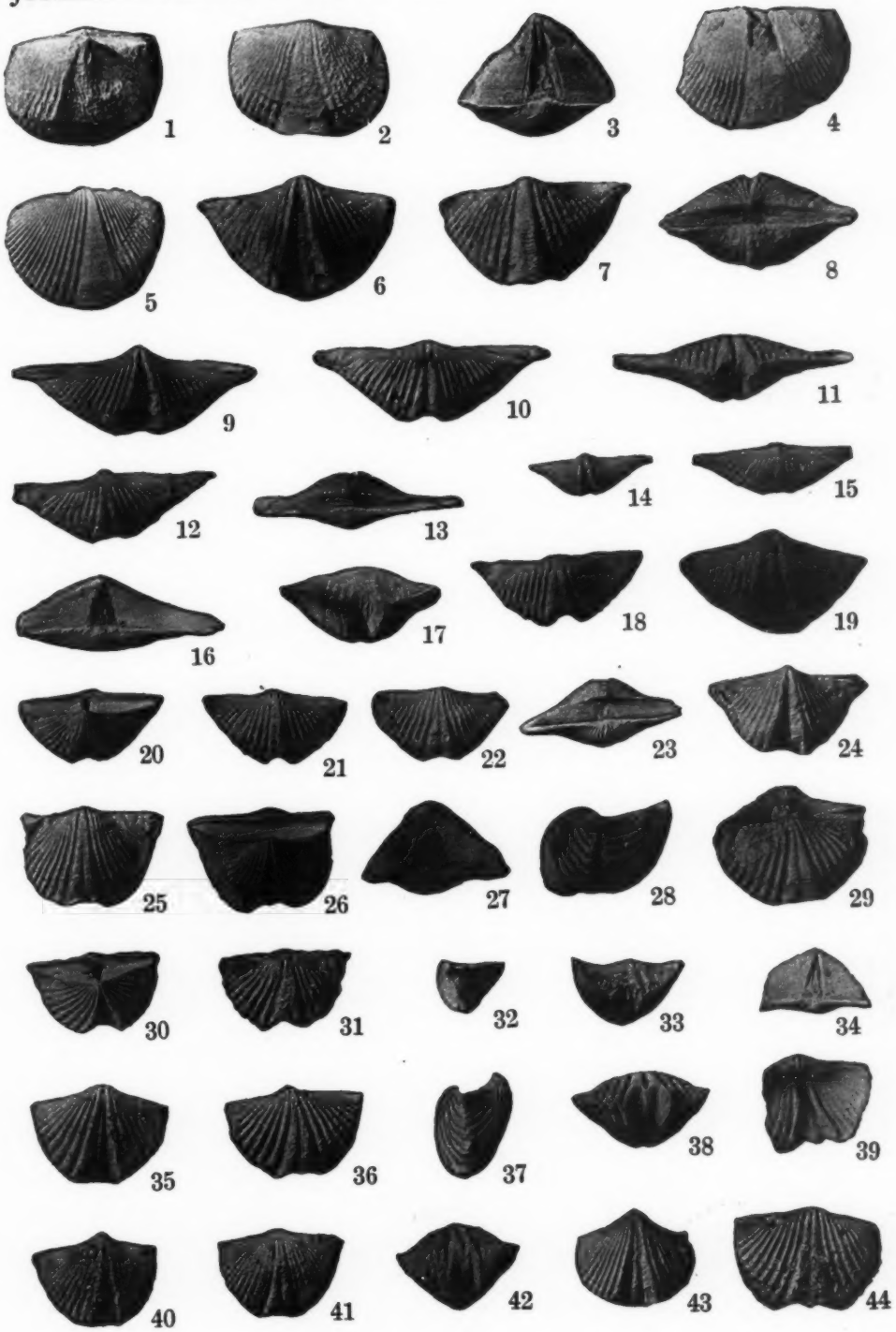
6–8, 19—Tylothyris megista Stainbrook, n. sp. *6–8*, Pedicle, brachial, and posterior views of the holotype (S.U.I. 6-446A). *19*, Pedicle view of a paratype (S.U.I. 6-446). Both from the *bellula* zone, Solon, Iowa. (p. 443)

9–15—Tylothyris bimesialis (Hall). *9–11*, Pedicle, brachial, and anterior views of a hypotype, which was compared with the type. *12, 13*, Brachial and posterior views of another. Both are (S.U.I. 6-450) from Independence, Iowa. *14, 15*, Pedicle and brachial views, respectively, of two hypotypes from Linn Junction, Iowa (M.A.S. 79). (p. 438)

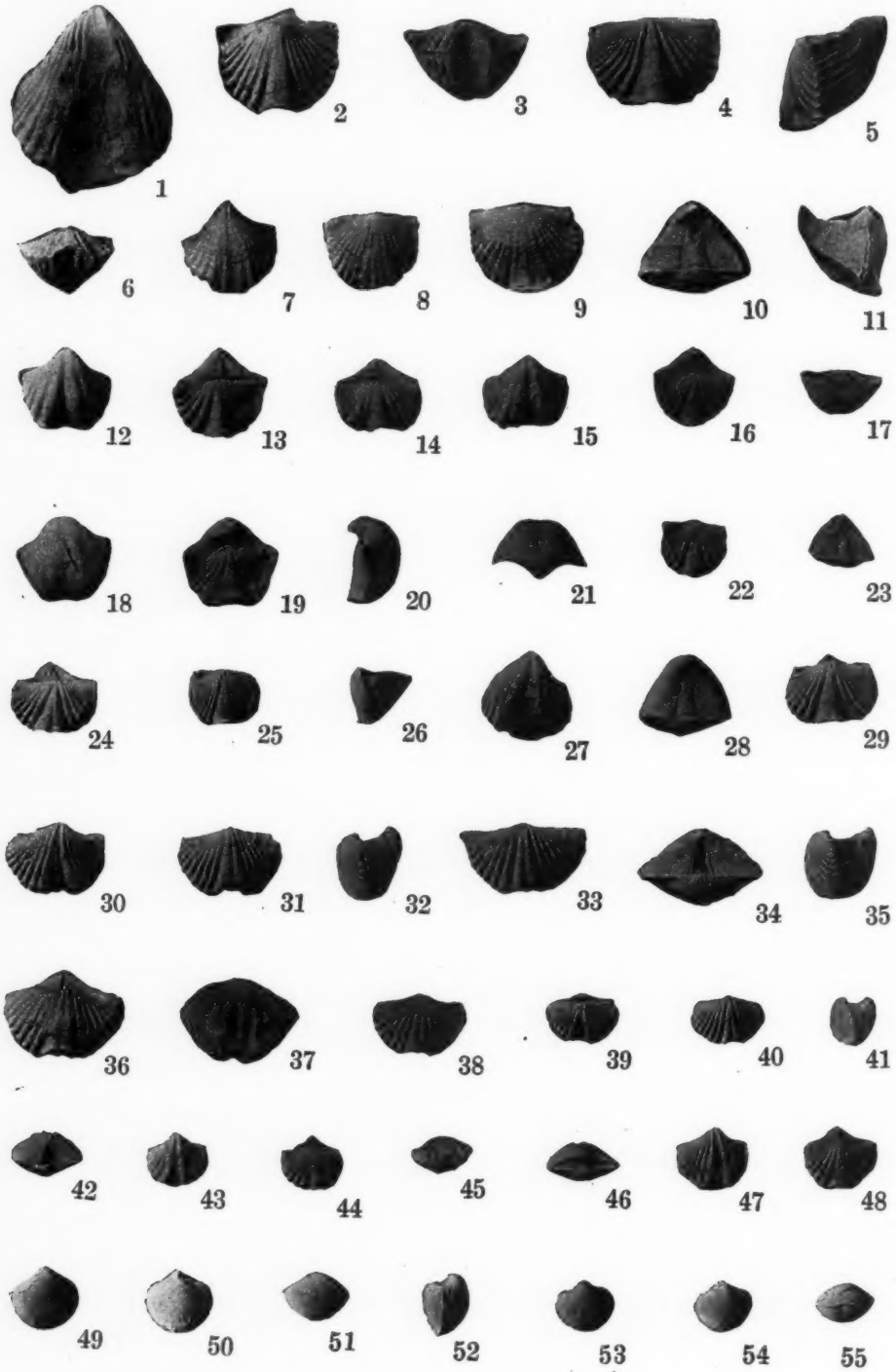
16–18, 20–24—Tylothyris subattenuata (Hall). *16*, Posterior view of a hypotype showing the high pedicle palintrope of this species (M.A.S. 1451). *17*, Anterior views of a hypotype (M.A.S. 1427). *18*, Anterior view of a hypotype (M.A.S. 1451). *20, 21*, Pedicle and brachial views of another. *22*, Brachial view of a hypotype (M.A.S. 1427). *23, 24*, Posterior and pedicle views of a hypotype (M.A.S. 1426). All from Independence, Iowa. (p. 442)

25–28, 30–34—Tylothyris inutilis (Hall). *25–27*, Brachial, pedicle, and posterior views of a large hypotype. *28*, Lateral view of another (M.A.S. 221), Waverly, Iowa. *30, 31*, Pedicle and brachial views of a specimen (S.U.I. 6-290), Linn Junction, Iowa. *32–34*, Lateral, anterior, and posterior views of a small example (M.A.S. 1393), Shellsburg, Iowa. (p. 440)

29, 35–44—Tylothyris randalia Stainbrook, n. sp. *29*, Brachial view of a paratype (M.A.S. 208), Randalia, Iowa. *35–38*, Pedicle, brachial, lateral and anterior views of a paratype (S.U.I. 6-100), Littleton, Iowa. *39*, Internal view of a brachial valve (S.U.I. 6-308), Brandon, Iowa. *40–42*, Pedicle, brachial, and anterior views of the holotype (M.A.S. 208A), Randalia, Iowa. *43*, Exterior view of a pedicle valve. *44*, Exterior view of a brachial valve. Both are (M.A.S. 1429) from Palo, Iowa. (p. 444)



Stainbrook, Devonian Brachiopoda



Stainbrook, Devonian Brachiopoda

vature greatest over the umbo, gently convex transversely in the middle portion and depressed toward the angles. Fold narrow, extending from the front margin to the beak, a little elevated above the remainder of the valve, flattened, divided mesially by a narrow sinus, which becomes obsolete on the umbo, shortened at the front by the extension of the opposite sinus, and bordered on either side by a narrow furrow; the mesial sinus may be obsolete in some examples. Lateral slopes very gently convex, a little curved anteroposteriorly and laterally from the fold, becoming concave toward the extremities, marked by plications of like number and appearance to those of the pedicle valve. Palintrope low, generally orthocline.

Surface of the valves marked by numerous close-set concentric growth lamellae. This species belongs to the genus *Tylothyris* as shown by the lamellose exterior, the pedicle septum and the large apical callosity. It is rather variable in size and shape and changes in appearance with maturity. The immature examples are considerably wider than long, elliptical in outline, with somewhat extended cardinal angles and with the lateral margins curving with moderate rapidity toward the front. The mature forms are proportionately longer, the pedicle valve may be highly subpyramidal, the angles but little extended, and the lateral margins abruptly curved from the angles to the front. The high triangular retrorse pedicle palintrope, the subpyramidal pedicle valve, and the slightly extended laterally curved angles distinguish this form from *Tylothyris bimesialis*. Short, wide examples of the ephebic stages of both species are somewhat similar, but the retrorse area will separate *Tylothyris inutilis* from the other.

Occurrence.—Cedar Valley limestone in the *independensis* zone at Independence, Linn Junction, Solon, Waverly, Vinton, Shellsburg, Cedar Rapids in Iowa. Also reported from Athabasca, Can.

Types.—Hypotypes are S.U.I. 6-448, 6-290 and 6-285, and M.A.S. 69, 92, 211, 217, 221, 260, 350, 348, 349, 1393, 1396.

EXPLANATION OF PLATE 70

FIGS. *1–5—Cyrtina robusta* Stainbrook, n. sp. *1*, Pedicle view of the holotype (S.U.I. 6-472A). *2*, *3*, Brachial and anterior views of a paratype (S.U.I. 6-472). Both from Independence, Iowa. *4*, *5*, Brachial and lateral views of a paratype (M.A.S. 220), Waverly, Iowa. (p. 448)

6–11—Cyrtina missouriensis (Swallow). *6–8*, Anterior, pedicle and brachial views of a small hypotype (M.A.S. 1430), Callaway limestone, Aux Vasse creek, Mo. *9–11*, Brachial, posterior and lateral views of a hypotype (M.A.S. 447), Buffalo, Iowa. This is the same as *Cyrtina curvilineata* White. (p. 447)

12–21—Cyrtina umbonata Hall. *12*, *13*, Pedicle and brachial views of a hypotype. *14*, *15*, Brachial and pedicle views of another. Both are (S.U.I. 6-467) from the *bellula* zone at Iowa City. *16*, *17*, Brachial and anterior views of a hypotype. *18–21*, Pedicle, brachial, lateral, and posterior views of a hypotype (M.A.S. 1388). Both from the *Stropheodonta parva* zonule, Buffalo, Iowa. (p. 446)

22–29—Cyrtina triquetra Hall. *22*, *23*, Brachial and posterior views of a hypotype. *24*, Brachial view of a hypotype. Both are (M.A.S. 78) from the *waterlooensis* zone at Littleton, Iowa. *25*, *26*, Brachial and lateral views of a hypotype (S.U.I. 6-469), *waterlooensis* zone, Littleton, Iowa. *27–29*, Pedicle, posterior, and brachial views of a large hypotype (M.A.S. 209), *waterlooensis* zone, Randalia, Iowa. (p. 446)

30–42—Tylothyris subvaricosa (Hall). *30–32*, Pedicle, brachial and lateral views of a hypotype (S.U.I. 6-298), *waterlooensis* zone, Littleton, Iowa. *33–35*, Brachial, posterior, and lateral views of a large hypotype (M.A.S. 204), *bellula* zone, Brandon, Iowa. *36*, *37*, Brachial and anterior views of a gibbous specimen. *38*, Brachial view of a specimen. Both are (S.U.I. 6-308) from the *waterlooensis* zone at Brandon, Iowa. *39–42*, Pedicle, brachial, lateral, and posterior views of a small example (M.A.S. 68), typical of the *profunda* zone, Brandon, Iowa. (p. 442)

43–48—Tylothyris annae (Swallow). *43–45*, Pedicle, brachial, and anterior views of a hypotype. *46–48*, Posterior, pedicle, and brachial views of a hypotype. Both are (M.A.S. 286) from the *Stropheodonta iowensis* zonule with *Cyrtina missouriensis* (Swallow) and *Eosyringothyris occidentalis* (Swallow) at Buffalo, Iowa. (p. 445)

49–55—Ambothyris halli (Branson). *49–52*, Pedicle, brachial, anterior, and lateral views of a hypotype. *53–55*, Pedicle, brachial, and anterior views of another. Both are (S.U.I. 6-474) base of the *profunda* zone, Independence, Iowa. (p. 449)

TYLOTHYRIS SUBATTENUATA (Hall)
Plate 69, figures 16–18, 20–24; text figures 13, 14

Spirifera submucronata HALL, 1858, Geol. Survey Iowa, vol. 1, pt. 2, p. 504, pl. 4, fig. 3. (*Spirifer submucronata* read *subattenuatus*) on plate explanation.

Shell of medium size, subelliptical in outline with sharply but briefly extended angles, broadly rounded anterolateral margins and short truncate front, nearly twice as wide as long with the greatest breadth along the hinge line, anterior commissure sinuate and dentate. Measurements of three hypotypes are: length 12.6 mm., 11.8 mm. and 12.9 mm.; width 23.2 mm., 22.3 mm. and 25.5 mm.; thickness 9.3 mm., 10.4 mm., and 13.5 mm.; height of pedicle palintrope 4.1 mm., 6.3 mm. and 6.4 mm.

Pedicle much the more convex, strongly arched along the midline from beak to front, strongly arched tranversely in the middle, highest in the umbonal region. Sinus originating at the beak, deep, generally having a median plication, exceptionally without and sharply angular at the bottom, continued at the front to form a short lingual extension. Slopes gently convex from back to front, curving strongly from the borders of the sinus at first and then gently to the lateral margins, concave in front of the angles. In some examples shelflike extensions are developed along the edges of the palintrope. Plications narrow, simple, subangular at the summit and numbering about 12. Umbo convex and elevated. Beak sharp, a little incurved and extending beyond the hinge line. Palintrope moderately high, the posterolateral margins sloping gradually from the beak to the extremities, but occasionally they may be high near the extremities; major portion near the hinge line is flat and catacline, curved beneath the beak. Delthyrium high and narrow. Internally the delthyrial supporting plates are short and strongly curved laterally. The apical callus is small and the median septum is low and thin but distinct.

Brachial valve gently convex, highest near the midpoint, gently curved from back to front and transversely, subquadrate to semielliptical in outline. Fold strong, but little elevated, beginning at the beak, generally divided in front by a sinus of variable length and strength and may be obsolete in some specimens. Umbo slightly convex; beak a little extended and incurving. Palintrope low, usually orthocline.

The plications, fold and sinus are marked by abundant well-developed growth lamellae. These with the impunctate shell substance, the transverse delthyrial plate, and the pedicle median septum place the species in the genus *Tylothyris*.

Tylothyris subattenuata occurs with the preceding species and seems to occupy an intermediate position as far as the external features are concerned. It is distinguished from *T. bimesialis* by its smaller, thicker, and narrower shell, less extended angles, and higher, less curved pedicle palintrope. Narrow examples of *T. bimesialis* with slightly extended angles are sometimes difficult to distinguish, but usually the high nearly flat palintrope is a ready means of separation.

T. subattenuata is near *T. inutilis* in size but differs from it in having a straight hinge line, more extended angles, less convex pedicle and brachial valves and a much lower nonretrorse pedicle palintrope.

Occurrence.—Cedar Valley limestone in the *independensis* zone at Independence and vicinity. The species has been reported elsewhere: by Clarke in the High Point fauna of New York, but the present writer did not recognize it among Clarke's specimens in the Schuchert collection recently studied; by Whiteaves from Athabasca River in Canada; and by Winchell in the Marshall group at Point aux Barques, Mich. The writer doubts that the latter identification is correct.

Types.—Hyotypes are M.A.S 1426, 1427 and 1428.

TYLOTHYRIS SUBVARICOSA (Hall and Whitfield)
Plate 70, figures 30–42; text figure 10

Spirifera subvaricosa HALL and WHITFIELD, 1872, New York State Cab. Nat. History Ann. Rept. 23, p. 237, pl. 11, figs. 12–15.

Spirifer subvaricosus, SCHUCHERT, 1897, U. S. Geol. Survey Bull. 87, p. 406.

Spirifer subvaricosus, CLELAND, 1911, Wisconsin Geol. and Nat. History Survey Bull. 21, p. 81, pl. 16, figs. 6–11.

Spirifer subvaricosus, BRANSON, 1924, Missouri Bur. Geology and Mines, ser. 2, vol. 17, p. 101, pl. 20, figs. 6–7; pl. 24, fig. 13.

Spirifer varicosus Hall. BRANSON, 1924, idem p. 102, pl. 19, fig. 18; pl. 21, figs. 4, 5; pl. 24, figs. 14, 15.

Shell small to medium in size, subequally biconvex, wider than long, subelliptical in outline, broadly rounded to the front along the lateral margins, typically a little extended at the angles, broadest along the hinge line. Measurements of three hypotypes from the *profunda* zone from three localities are: length 9.6 mm., 8.6 mm. and 7.5 mm.; width 17.8 mm., 15.7 mm. and 11.4 mm.; thickness 10.8 mm., 9.6 mm. and 7.1 mm.

Pedicle valve arching with moderate regular curvature along the bottom of the sinus to the front, strongly and evenly convex transversely, highest near the beak, the surface sloping rapidly thence to the anterior and lateral margins. Sinus originating at the beak, deep, relatively narrow, the sides flat and dropping abruptly from the upper margins; along the bottom is a single sharply angular plication extending from the front margin nearly to the beak. Umbo convex, elevated; beak strong, pointed, slightly incurved and occasionally a little twisted. Lateral slopes gently curved from beak to front, slightly concave in front of the angles, marked by strong angular simple plications. The latter decrease in size toward the angles, average about eight on each slope, and are separated by deep, narrow furrows. Palintrope high, flat in the lower part, curved beneath the beak, vertically and horizontally striated, horizontally striated only near the lateral margins, slightly procline in immature specimens to a little aspacline in adults; its lateral margins angular and sloping rapidly from the beak to the extremities. Delthyrium narrow, nearly twice as high as the width at the base. Internally the delthyrial supporting plates are thin and delicate, concave anteriorly and extended for a short way forward along the floor of the valve. Between the plates is a small apical callosity which is concave anteriorly. Extending forward from the apex to the midlength is a thin erect median septum about a millimeter high near its anterior extremity.

Brachial valve much less convex than the pedicle, moderately arched from beak to front, with the greatest curvature in the umbonal region, gently and regularly arched transversely, highest near the middle. Fold distinctly composed of two plications, larger and more elevated than the remainder, and separated by a deep, fairly wide sinus, which extends to the beak from the front margin. Lateral slopes gently curved from the hinge line to the front and from the fold to the sides, a little depressed in front of the angles, bearing plications like those of the opposite valve. Beak blunt, a little curving and projecting. Palintrope linear, divided by a broad, low notothyrium.

Fold, sinus and slopes marked by numerous strongly lamellose lines of growth, more or less regularly spaced and looping posteriorly along the summits of the plications. In well-preserved specimens the surface also shows numerous fine radial striae.

Internally the cardinal process is short, narrow and vertically striated. The sockets deep, laterally directed and open anteriorly. The crural plates are strong and extend posteriorly to the floor of the valve. A low but distinct median septum extends anteriorly to the midpoint. The species described by Branson as *Spirifer varicosus* Hall seems to be this species.

Occurrence.—Cedar Valley limestone: the type specimen came from the *profunda* zone at Waterloo, but it also occurs at Jesup, Brandon, Littleton and Vinton; found also in the *bellula* zone at Brandon, Iowa City and Buffalo; *waterlooensis* zone at Brandon and Littleton, Iowa. Milwaukee formation at Milwaukee, Wis. Mineola limestone of Ralls County, Mo.

Types.—Hypotypes are S.U.I. 6-297, 6-298, 6-310, 6-311 and 6-284; M.A.S. 68, 128, 268, 204, 347, 1394 and 1404.

TYLOTHYRIS MEGISTA Stainbrook, n. sp.

Plate 69, figures 6–8, 19

Shell above medium size, subequally biconvex, much wider than long, broadest along the hinge line, transversely semielliptical with extended angles, short front margin, and long anterolateral margins. Dimensions

of the holotype and of a paratype are: length 15.5 mm. and 13.4 mm.; width 28.8 mm. and 26.7 mm.; thickness 13.4 mm. and 13.2 mm.

Pedicle valve moderately convex, highest near the middle, arching with regular curvature from the beak to the anterior margin along the bottom of the sinus, evenly convex transversely. Sinus extending from beak to front, bordered on either side by a plication stronger than those on the slopes, broad, moderately deep, the bottom wide and marked by a broad, low mesial plication, which extends from the anterior margin nearly to the umbonal region, and which may be nearly obsolete in some specimens. Lateral slopes curving with moderate rapidity from the cardinal margin anteriorly and from the sinus toward the sides, a little depressed near the angles. Each fold bears 13–15 low, subangular, simple plications, which are separated by furrows half as wide. Palintrope low, strongly curved beneath the beak, catacline; its borders sloping strongly from the beak and then gradually to the extremities. Umbo convex, a little elevated; beak slightly projecting beyond the hinge line, incurved.

Brachial valve about as convex as the pedicle, arched from beak to front with the greatest curvature in the umbonal region, highest in the middle and arched from side to side. Fold originating at the beak, becoming higher and wider to the anterior margin, elevated above the remainder of the valve, flattened at the summit, whence the sides descend abruptly, and depressed mesially by a more or less distinct broad sinus. Lateral slopes gently convex, curving from the hinge line to the front margin and from the fold to the extremities, depressed in front of the angles, occupied by plications similar to those on the pedicle valve. Umbonal region regularly convex; beak small but little projecting; palintrope linear. Plications, fold and sinus strongly marked by lamellose concentric growth lines.

Tylothyris megista differs from *Tylothyris bimesialis* in its larger size, proportionally greater length, and less distinct sinus on the fold of the brachial valve. It is larger than *Tylothyris inutilis*, differently shaped, and does not have as high a palintrope. Its large size will separate it readily from other members of the genus occurring in this formation. It resembles *Spirifer pennatus* (Atwater) but differs in having a much higher area, less extended angles, a more convex brachial valve, a distinct sinus on the brachial fold, and a flat-bottomed sinus in the pedicle valve.

Occurrence.—Cedar Valley limestone in the *Pentamerella* zone at Rapid Creek in Johnson County and at Brandon, Iowa.

Types.—Holotype S.U.I. 6–446, paratype 6–446B and C; M.A.S. 116, 118 and 1393.

TYLOTHYRIS RANDALIA Stainbrook, n. sp.
Plate 69, figures 29, 35–44

Shell small to medium in size, unequally biconvex, wider than long, broadest along the hinge line, subquadrate in outline, with slightly but acutely extended angles, long gently curving lateral margins and short truncate front margin. Measurements of the holotype and a paratype are: length of brachial valve 12.8 mm. and 13.8 mm.; width 18.1 mm. and 21.8 mm.; thickness 12.2 mm. and 11.4 mm. (crushed). A crushed specimen has a brachial valve 14.4 mm. long and 24.4 mm. wide.

The pedicle valve is strongly convex, subpyramidal, gently arched along the bottom of the sinus, strongly arched from side to side, highest in the umbonal region, whence the surface slopes rapidly to the lateral margins. Sinus extending from beak to front, narrow, of moderate depth, bordered on either side by plications slightly larger than the remainder. A strong plication occupies the bottom of the sinus and extends posteriorly to the umbo; on a large gerontic pedicle valve the plication is bifurcate. Lateral slopes slightly curved from back to front, marked by 12 low, simple, narrow, angular-bottomed furrows. At the angles may be two or three small indistinct additional plications. Umbo elevated, laterally compressed a little; beak short, pointed, and slightly incurved. Palintrope high, flat for the greater part, slightly curved near the beak, apsacline in neanic specimens, catacline in adults; a distinct groove is present on either side of the pedicle opening. Delthyrium high, narrow, open to the apex. Internally the apical callus is very small, the median septum low, thin, and extended to the midpoint. The

delthyrial supporting plates are thin, short and delicate.

Brachial valve moderately convex, regularly arched from beak to front and transversely. Fold originating at the beak, depressed centrally by a deep, narrow median sinus, so that it appears as two large plications, and shortened anteriorly by the lingual extension of the pedicle sinus. Slopes depressed, a little concave in front of the angles, bearing plications as on the opposite valve. Umbo inconspicuous; beak small, a little projecting and incurving. Palintrope very low, orthocline, and divided by the broad low notothyrium. Internally the cardinal process is weakly developed and vertically striated. The dental sockets are deep, short, and of moderate width at the open anterior ends.

Slopes of both valves, fold, and sinus marked by abundant imbricate growth lamellae. In well-preserved specimens fine, minute radiating lines mark the surface of the valves.

Tylothyris randalia is near *T. subvaricosa* but is distinguished by the much larger size, proportionately longer shell, higher pedicle palintrope, and more numerous, narrower, and more closely aggregated plications. Its size and narrowness will readily separate it from other members of the genus in the Cedar Valley beds.

Occurrence.—Cedar Valley limestone in the *waterlooensis* zone at Randalia, Palo and Brandon, Iowa.

Types.—The holotype is M.A.S. 208A; paratypes are S.U.I. 6–308 and M.A.S. 208 and 1429.

TYLOTHYRIS ANNAE (Swallow)
Plate 70, figures 43–48

Spirifer annae SWALLOW, 1860, St. Louis Acad. Sci. Trans., vol. 1, p. 641.
Spirifer annae, SCHUCHERT, U. S. Geol. Survey Bull. 87, p. 381.
Spirifer annae, BRANSON, 1924, Missouri Bur. Geology and Mines, ser. 2, vol. 17, p. 99, pl. 19, figs. 13, 15–17; pl. 24, fig. 17.

Shell small, subequally biconvex, wider than long, the hinge line equalling or less than the greatest width, transversely semielliptical, the cardinal angles slightly rounded or a little extended. Dimensions of two hypotypes are: length 7.8 mm. and 6.2 mm.; width 11.6 mm. and 10.2 mm.; thickness 7.7 mm. and 5.7 mm.

Pedicle valve highly convex, subpyramidal, highest at the beak, gently curved from beak to front along the midline. Sinus originating at the beak and extending to the anterior margin, not plicate, flat or very gently convex along the bottom, the sides low and steeply sloping, the front continued to form a short quadrate lingual extension. Lateral slopes gently curved from the hinge line to the anterolateral margins, bearing on the average eight stout simple plications, rather angular at the summit, sharply separated by narrow furrows, and decreasing in size toward the angles. Beak prominent, pointed, a little incurved. Palintrope high, flat for the most part, apsacline, sometimes moderately concave, a little curved beneath the beak, horizontally striated, the lateral margins angular and sloping sharply from the beak to the extremities. Delthyrium high and narrow. Serial sections of the beak reveal the presence internally of a small apical callus, of short delthyrial supporting plates, and of a low but distinct median septum.

Brachial valve much less convex than the pedicle, gently arched from beak to front, highest in the middle, regularly arched from side to side. Fold strong, extending the full length of the valve, slightly elevated, bordered at the sides by furrows larger than those on the slopes, the summit flat, with the sides nearly at right angles. Lateral slopes gently curved from the hinge line to the front, sloping gently toward the extremities, slightly flattened at the angles, marked by plications similar in number and appearance to those of the pedicle slopes. Beak small, slightly projecting. Palintrope linear and divided by a broad, low delthyrium.

Surface of the fold, slopes and sinus marked by numerous regularly spaced lamellose growth lines. The nonplicate fold and sinus, small size, and usually rounded angles are features which will distinguish this form from other members of the genus.

The internal characters of the pedicle valve noted above with the lamellose surface place this form in the genus *Tylothyris*. The specimens on which the above description was based were compared with hypo-

types in the University of Missouri museum and were found to be identical.

Occurrence.—Cedar Valley limestone in the *Stropheodonta iowensis* zonule at Buffalo, Iowa; Callaway limestone and Snyder Creek shale of Missouri.

Types.—Hypotypes are S.U.I. 6–451 and 6–310; M.A.S. 155 and 286.

Family SPIRIFERINIDAE Davidson
Subfamily CYRTININAE Schuchert and Le Vene
Genus CYRTINA Davidson
CYRTINA UMBONATA Hall
Plate 70, figures 12–21

Cyrtina umbonata HALL, 1858, Geology of Iowa, vol. 1, pt. 2, p. 512, pl. 5, fig. 2.
Cyrtina umbonata, MILLER, 1889, North American Geology and Paleontology, p. 343.

Shell small, nearly plano-convex in shape, a little wider than long, widest along the hinge line or in front of it, the anterolateral margin broadly curved to the front, the posterolateral margins nearly straight and meeting sharply in an obtuse angle at the back, cardinal angles slightly, sometimes acutely, extended. Measurements of two hypotypes are: length 10.9 mm. and 11.9 mm.; width 11.4 mm. and 13.4 mm.; thickness 6.6 mm. and 7.2 mm. Incomplete individuals at hand indicate that greater dimensions may be attained.

Pedicle valve more convex and longer than the brachial, greatly and regularly arched along the midline from back to front with the curvature increasing over the umbo, highest at the midpoint. Mesial sinus extending from beak to anterior margin, shallow, broadly rounded at the bottom, bordered at the sides by plications larger than the remainder, extended in front into a short rounded lingual extension. Lateral slopes strongly curved from the cardinal margin to the front near the mesial sinus, gently so near the angles, incurved beneath the beak. Plications simple, gently rounded, variable in strength and number, divided by furrows of less width, extending to the beaks in some specimens, obsolete on the umbo in others, ranging from seven to ten in number, most specimens having about eight on each slope. Umbonal region strongly convex and elevated, projecting beyond the hinge line. Beak strong, sharp, incurved. Palintrope broadly triangular, apsacline, concave, horizontally and vertically striated, its lateral margins distinct and slightly angular; delthyrium almost completely covered by a low convex deltidium, open only at the base and at the apex.

Brachial valve depressed, very gently convex, or nearly flat. Mesial fold well developed, originating at the beak, increasing in width more rapidly near the front, strongly convex, rounded along the summit, elevated above the slopes, bordered at the sides by furrows wider and deeper than the remainder. Lateral slopes nearly flat, sloping gently from the fold to the angles, marked by plications similar to those on the pedicle valve. Umbonal region very gently convex; beak low, blunt, scarcely projecting; area linear.

Surface of both valves marked by numerous fine concentric striae of growth, occasionally lamellose, and usually more numerous near the front margin. Shell substance punctate.

The strongly curved pedicle valve, generally nonangular fold and sinus, and slightly extended cardinal angles readily identify this species. In the *bellula* zone occurs a variety differing from the typical form described above by these characters: the cardinal area is not as curved; the fold and sinus are more angular, the sinus is also deeper; the plications are fewer and more strongly developed. This variety resembles somewhat the form described from Michigan by Hall and Clarke as *Cyrtina umbonata alpenensis.*

Occurrence.—Cedar Valley limestone in the *Pentamerella* zone, *Stropheodonta parva* zonule at Buffalo, Linwood and Moscow. Varietal form from the *bellula* zone at Buffalo, Linwood, Moscow, and Johnson county.

Types.—Hypotypes S.U.I. 6–467 and M.A.S. 214, 278, and 63.

CYRTINA TRIQUETRA (Hall)
Plate 70, figures 22–29

Cyrtia triquetra HALL, 1858, Geology of Iowa, vol. 1, pt. 2, p. 513.
Cyrtina triquetra, MEEK and WORTHEN, 1868, Illinois Geol. Survey, vol. 3, p. 436, pl. 13, fig. 4.
Cyrtina triquetra, HALL and CLARKE, 1895, New

York Geol. Survey Paleontology, vol. 8, pt. 2, pl. 28, figs. 34, 35.
Cyrtina triquetra, SCHUCHERT, 1897, U. S. Geol. Survey Bull. 87, p. 199.

Shell small, very unequally biconvex, wider than long, broadest along the hinge line or anterior to it, a little extended at the cardinal angles in youthful specimens, and less produced there in the later stages. Dimensions of several hypotypes are: length of brachial valve 6.8 mm., 7.2 mm., 7.3 mm. and 8.6 mm.; width 10.4 mm., 10.5 mm., 12.8 mm. and 13.1 mm.; thickness 7.5 mm., 9.1 mm., 9 mm. and 10.6 mm. A pedicle valve measures 9.6 mm. in length, 13.7 mm. in width and 10.4 mm. in depth. Larger specimens also occur. Usually examples from one zone are nearly all the same size.

Pedicle valve strongly subpyramidal, highest at the beak, the surface sloping abruptly thence to the front and lateral margins, gently curved along the bottom of the sinus from the anterior margin to the beak. Mesial sinus extending the full length of the valve, strong, deep, angular along the bottom, the sides merging outwardly with the bounding plications, the front portion forming a short lingual extension. Slopes gently curved from the cardinal margin toward the front and from the sinus to the angles. Plications simple, continuing from the margins to the beak, narrow, of moderate size, rounded to subangular at the summit, separated by narrower furrows, decreasing in size away from the sinus, and numbering about eight to ten. Beak highly elevated, generally twisted, sharply pointed, sometimes strongly or not at all incurved. Palintrope high, usually wider than high, but higher than wide in some examples, flat or gently curved near the beak, apsacline, catacline, and even procline, horizontally and vertically striated; lateral margins sharply angular, nearly straight from the beak to the extremities. Delthyrium narrowly triangular, covered except near the apex by a broadly convex deltidium.

Brachial valve subquadrate in outline, with the lateral margins straight or gently curved and making a right angle with the hinge line, nearly flat and gently convex transversely in the middle. Mesial fold originating at the beak, becoming wider and higher more rapidly near the front, elevated above the remainder of the valve, strongly convex, flattened a little along the crest and showing there in numerous specimens a faint indication of a mesial sinus, the sides sloping abruptly to the bordering furrows, which are deeper and wider than those between the plications. Lateral slopes very gently curved in the posterior portions and from the fold to the lateral margins, bearing plications similar to those of the opposite slopes. Umbonal region gently convex; beak short, blunt. Surface of both valves marked by numerous fine lines of growth, occasionally lamellose. Punctae are scattered, not always readily apparent.

In the neanic stage the cardinal angles are slightly extended, the area flat and even retrorse and much wider than high, the fold with no indication of a median sinus and the sinus without a plication. In the later stages the angles are not extended, and the greatest width is anterior to the hinge line; the palintrope is often higher than wide, curved, and inclined posteriorly; there is more indication of a mesial sinus on the fold. A specimen at hand, a gerontic form, has a well-developed sinus on the fold and a plication in the pedicle sinus.

Cyrtina triquetra is smaller than *Cyrtina hamiltonensis*, is not as extended at the angles in the mature stage, has from three to four more plications on the slopes, and lacks the oblong surface granules of the former. It has been reported from the Snyder Creek shale of Missouri, but our specimen from that formation is distinct. *Cyrtina hamiltonensis* from the Mineola, as figured by Branson, appears to be near *Cyrtina triquetra*.

Occurrence.—Cedar Valley limestone in the *profunda* zone up to the *Cranaena iowensis* zone, most common in the *waterlooensis* zone; Iowa City, Randalia, Buffalo, Brandon, Littleton, Waterloo and elsewhere in Iowa. Reported from Rock Island, Ill., and present in the Milwaukee beds at Milwaukee, Wis.

Types.—Hypotypes: S.U.I. 6–470, and 6–469, and M.A.S. 70, 222, 209, 78, 80, 127, and 1431.

CYRTINA MISSOURIENSIS (Swallow)
Plate 70, figures 6–11

Cyrtia missouriensis SWALLOW, 1860, St. Louis Acad. Sci. Trans., vol. 1, p. 647.

Cyrtina missouriensis, MILLER, 1889, North American Geology and Paleontology, p. 343.
Cyrtina missouriensis, SCHUCHERT, 1897, U. S. Geol. Survey Bull. 87, p. 198.
Cyrtina missouriensis, BRANSON, 1923, Missouri Bur. Geology and Mines, ser. 2, vol. 17, p. 108, pl. 16, fig. 9; pl. 19, figs. 1–4.
Cyrtia curvilineata WHITE, 1862, Boston Soc. Nat. History Proc., vol. 9, p. 25.
Cyrtina curvilineata, HALL, 1867, New York Geol. Survey Paleontology, vol. 4, p. 270, pl. 44, figs. 53–55.
Cyrtina curvilineata, HALL and CLARKE, 1895, idem, vol. 8, pt. 2, pl. 28, figs. 11, 12.

Shell small, subpyramidal, subquadrate in outline, wider than long, with the greatest width along or anterior to the hinge line. Dimensions of a hypotype: length 12.1 mm.; width 16 mm.; thickness 11.5 mm.

Pedicle valve strongly arched from beak to front, acutely arched transversely, highest in the umbonal region, the surface sloping abruptly to the front and lateral margins. Sinus extending from beak to front, broad, shallow, plicate, and extended anteriorly. Slopes gently curved from the beak to the lateral margins and from the sinus to the margins of the area. Beak strong, pointed, slightly twisted, highly elevated and a little incurved. Palintrope large, triangular, often about as high as wide, flat to gently concave, transversely striated, varying from catacline to apsacline, sharply angular at the sides, which slope abruptly from the beak to the extremities. Delthyrium about three times as high as it is wide at the base, covered by a convex deltidium in the lower part.

Brachial valve gently arched from beak to front and from side to side, slightly convex in the umbonal region, depressed a little near the angles and anteriorly on either side of the fold. Fold originating at the beak, broad, low, elevated at the front, flattened or gently convex along the summit, plicate or bordered at the sides by furrows deeper than those on the slopes.

Surface of both valves marked by low, narrow plications, extending from the beak to the margins in most cases, subangular along the crests, separated by narrow furrows, irregularly increasing by division, numbering about eight or nine on each slope; three or four larger plications of variable size and length occupy the fold. Numerous close-set imbricating lamellose concentric lines of growth cross the valves.

The species is rare in Iowa, about four specimens being known to us; two, the types of *Cyrtina curvilineata*, are in the museum of the University of Michigan, no. 4846; one described by Hall in the American Museum of Natural History, and one is in the writer's collection. While the type specimens of *Cyrtina curvilineata* have not been compared with examples of *Cyrtina missouriensis*, there seems little doubt that the forms are the same. The Iowa specimen of *C. missouriensis* is similar in all respects to numerous examples from the Callaway limestone of Missouri.

Horizon and localities.—*Waterlooensis* zone at Iowa City, *Stropheodonta iowensis* zonule of this zone at Buffalo; Callaway limestone of Missouri.

Hypotype.—M.A.S. 499, and 1430 (Callaway limestone).

CYRTINA ROBUSTA Stainbrook n. sp.
Plate 70, figures 1–5; text figure 7

Shell of medium size, inequally biconvex, subpentagonal in outline, wider than long, with the greatest width along the hinge line or anterior, having the cardinal angles slightly extended or shortened, and strongly sinuate along the front margin. Dimensions of the holotype and of two paratypes are: length 11.5 mm., 16.5 mm. and 19.6 mm.; width 17.7 mm., 18.3 mm. and 22.8 mm.; thickness 15.3 mm., 13.5 mm. and 11.1 mm. (incomplete). A nearly complete specimen is 19.3 mm. long and 25.1 mm. wide.

Pedicle valve strongly convex, subpyramidal, highest in the umbonal region, in most specimens strongly arched along the bottom of the sinus from the midpoint to the beak and less strongly thence to the front margin. Sinus originating at the beak, widening and deepening to the anterior margin, shallow, concave along the bottom in the anterior portion and angular near the beak, extended at the front, the lateral margins distinct and formed by plications no larger than the others. Lateral slopes strongly curved from the back to front near the sinus and gently near the angles, sloping strongly from the sinus to the lateral margins. Plications number about ten on each slope, simple, narrow, subangular, those

near the sinus extending to the beak, decreasing in size toward the angles, and separated by narrow furrows. Umbonal region prominent, greatly elevated, more convex on one side than the other. Beak strong, sharply pointed, directed to one side, strongly incurved, or not at all. Palintrope high, varying from flat to strongly curved especially beneath the beak, strongly apsacline to catacline in lower portion, wider than high, transversely and vertically striated. Delthyrium narrow, triangular, the height three times the width at the base, closed except toward the apex by a moderately convex deltidium. Internally the median septum is well developed and extends along the floor of the valve to within five or six millimeters of the front margin.

Brachial valve nearly flat, gently elevated centrally. Fold strong, elevated above the slopes, bordered at the sides by furrows deeper and wider than the remainder, broadly convex, flattened a little along the summit in the posterior portion, increasing more rapidly in width as the front is approached, shortened anteriorly. Lateral slopes depressed convex, very gently curved from the cardinal margin anteriorly and from the fold to the angles, slightly concave in front of the angles, bearing plications of like number and appearance to those of the opposite valve. Umbonal region weak; beak scarcely projecting. Concentric growth lines of variable strength common on both valves. Shell substance abundantly punctate.

This species has commonly been referred to *Cyrtina hamiltonensis* but differs considerably from that form. *Cyrtina robusta* is larger, has but slightly extended or rounded angles, has more plications, has the sinus rounded at the bottom instead of angular at the front margin, and has a proportionately larger brachial valve. *Cyrtina robusta* is more than three times as large as *Cyrtina triquetra*, has coarser plications, and has the beak more twisted.

Occurrence.—Cedar Valley limestone in the *independensis* zone at Independence, Waverly, Vinton, Solon, Linn Junction, Davenport, and Buffalo, Iowa.

Types.—Holotype S.U.I. 6–472A; paratypes 6–472 and M.A.S. 205, 47, 218, 220, 198, 213, and 212.

Subfamily AMBOCOELIINAE George, 1931
Genus AMBOTHYRIS George, 1931

Hinge line advanced, forming the greatest, or nearly the greatest, width of the shell. Ventral umbo primitive, feebly incurved. Surface-ornament (? smooth to) planistriate. Internal features other than crural plates, unknown (George, 1931).

Genotype, *Spirifer infimus* Whidborne. Middle Devonian of Devonshire.

AMBOTHYRIS HALLI (Branson)
Plate 70, figures 49–55; text figure 12

Martinia halli BRANSON, 1924, Missouri Bur. Geology and Mines, ser. 2, vol. 17, p. 106, pl. 16, figs. 6–8.

Shell small, unequally biconvex, subovate in outline, with rounded cardinal angles and the lateral margins curved gradually to the front, wider than long, the greatest width posterior to the midlength, the hinge line less than the greatest width. Dimensions of several hypotypes are: length 8.4 mm., 8 mm. and 7.5 mm.; width 8.8 mm., 8.1 mm. and 7.5 mm.; thickness 6.2 mm., 6.3 mm. and 5 mm.

Pedicle valve strongly arched from beak to front, with the greatest convexity posterior to the midlength, more abruptly and evenly arched transversely; the surface sloping rapidly from the umbo to the front and lateral margins and strongly inflected beneath the beak to the cardinal margin; the anterior mesial portion slightly produced; extending along the midline from beak to front is a very slight indication of a mesial furrow. Umbonal region prominent, a little projecting; beak large, elevated, incurved. Area small, triangular, curved, with the lateral margins merging with the slopes. Internally there is no prominent structure revealed by serial sectioning.

Brachial valve less convex than the pedicle, most convex in the umbonal region, the surface sloping with moderate rapidity to the front and lateral margins and more rapidly to the hinge line, transversely elevated a little along the midline but not into a distinct fold. Internally there are two strong crural septa connected posteriorly with the hinge plate, extended along the floor of the valve one-fourth its length and situated near each other on either side of the median line. The surface of both valves

smooth, marked by a few concentric striae of increment.

This small shell has not yet been placed definitely in its proper generic position. The presence of well-developed septa in the brachial valve removes it from the genus *Martinia*. It resembles *Ambocoelia* in some of its external features but is more strongly biconvex, has a deeper brachial valve, has no surface spinules and the pedicle sinus is very weakly or not at all developed. Internally the septa of the brachial valve are longer, higher, thinner and differently shaped and have their bases closely approximated on the floor of the valve so as to form a V-shaped structure there. This species does not seem to be referable to *Ambocoelia*. In external appearance it resembles the genotype of *Ambothyris*. However until the internal structures of that genus are better known, reference of our form to it can only be tentative and subject to future revision.

In general appearance *Ambothyris halli* is similar to *Spirifera glanscerasi* White, of which the type specimens are preserved in the museum of the University of Michigan. Direct comparison of specimens with the type has not yet been possible, and reference of *Ambothyris halli* to this form cannot be made. The illustrations of *Spirifera maia* given by Walcott (1884, pl. 3, figs. 1c, 1d) indicate a form similar to *Ambothyris halli*. Specimens from Iowa were compared with the types of *Martinia halli* in the museum of the University of Missouri and were found to be the same.

Occurrence.—Cedar Valley limestone in the base of the *profunda* zone at Independence, Jesup, Cedar Rapids, and Brandon, Iowa. Callaway limestone of Missouri.

Types.—Cotypes 3338, University of Missouri.

Hypotypes.—S.U.I. 6–474; M.A.S. 40 and 1281.

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LOWER CRETACEOUS CRINOIDS FROM TEXAS

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ABSTRACT—Small stemless highly ornamented crinoid calyces and free brachials are abundant in the Fredericksburg and Washita groups of the Lower Cretaceous of Texas. They are referred to a new family, the Roveacrinidae, and to six genera, four of which are new. The new genera are *Discocrinus*, *Plotocrinus*, *Poecilocrinus*, and *Orthogonocrinus*.

The Roveacrinidae closely resemble the comatulids but, instead of cirri, possess horizontal and vertical flanges, spines, nodes, and corrugations. They developed from a stemmed ancester and became highly modified for a passive floating existence. The Roveacrinidae are excellent stratigraphic fossils. Species are widely distributed, easily identified, and have short vertical ranges.

INTRODUCTION AND ACKNOWLEDGMENTS

With the exception of *Uintacrinus socialis* from the Niobrara of Kansas, crinoids have been considered a rarity in the North American Cretaceous. Biese and Sieverts-Doreck (1937) list only six species, three of which are represented by columnals only, and three by calyces. None of these is from the Lower Cretaceous. It was with considerable surprise, therefore, that I discovered in the spring of 1941 that small stemless calyces and free brachials occur literally by thousands in the Lower Cretaceous of Texas.

These crinoids were first brought to my attention by Mr. Claude Quigley, a graduate student at the University of Missouri, who was examining a sample of the Duck Creek formation for microfossils. Inquiry on my part among paleontologists familiar with the Lower Cretaceous faunas disclosed that several people had noted the occurrence of the crinoids, and that Dr. Alfred R. Loeblich and Dr. Helen Tappan (Mrs. A. R. Loeblich) had picked out the crinoid calyces from the extensive series of samples gathered in the course of their investigation of the micropaleontology of the Lower Cretaceous of Texas. As my collection was interesting but extremely limited in scope, the Loeblichs generously placed their entire crinoid collection at my disposal. They carefully labeled and sent me crinoids from several hundred samples and furnished also a complete list of their collection localities and sample distribution. I have thus been able to study the crinoids of a representative cross section of the Lower Cretaceous of Texas. Enough samples from various localities have been examined to give a fairly accurate account of the vertical range and horizontal distribution of the species.

Lower Cretaceous crinoids have been mentioned only a few times in the literature, and none have been described from America. Several county reports and other papers dealing with Lower Cretaceous paleontology and stratigraphy of Texas mention the presence of echinoderm fragments, and Winton (1925) illustrated some of the calyces and brachials. His plate 16, figure 1, listed as the "apical system of an echinoderm" is probably *Roveacrinus pentagonus;* figures 24–26 on the same plate listed as "unidentified" are brachials; figures 2 and 3 on plate 24 are oral views of either *Roveacrinus latealatus* or *Poecilocrinus dispandus;* figures 10 and 11 are probably crinoids, and figure 12 is the exterior of the first primibrach of *Plotocrinus* sp.

Mrs. Vaona Hedrick Peck retouched and arranged the photographs on plates 1–6, and made the drawings for text figures 1–22. The retouched photographs are as accurate as it is possible to make them. No restorations have been made.

Dr. E. B. Branson of the University of Missouri and Dr. Edwin Kirk of the United States Geological Survey have read the manuscript and offered valuable suggestions.

All figured types have been given numbers and deposited in the Micropaleontology Collections at the University of Missouri. Unfigured paratypes have been placed in the Loeblich Collection and in the United States National Museum.

MORPHOLOGY

The small, simple crinoids from the Lower Cretaceous of Texas, here referred to the Roveacrinidae, have perfectly pentamerous calyces composed of five radials only (pl. 76, fig. 20), or five radials with noncirriferous centrodorsals (pl. 71, figs. 9, 17; pl. 72, figs. 1, 8). I have not found a trace of basals, infrabasals, or anals in even the smallest and most immature calyces (pl. 71, fig. 10; pl. 76, figs. 11, 12). Some calyces are almost devoid of ornamentation, others are highly ornamented with horizontal and vertical flanges, spines, nodes, or corrugations. The plates are fairly thick and massive but very porous. Sides of adjoining radials thicken and form slight to heavy ridges along the interradial sutures externally and internally. The sides of adjoining radials extend distally to form characteristic strong processes between the arm facets (pl. 71, figs. 21–24). The calyx cavity is divided into two parts, a distal body cavity and a proximal centrodorsal cavity, by a horizontal partition resembling and corresponding in position to, and probably homologous with, the rosette of the comatulids (pl. 71, fig. 9; pl. 72, figs. 1, 6, 8, 10, 25; pl. 74, fig. 2; pl. 76, figs. 8, 26).

The radial arm facets are well developed. The ligament pit and central canal are both prominent. The inarticular ligament fossae and dorsal ligament fossae occupy most of the facet. The muscular fossae are small, linear, and excavated in the sides of the interfacet processes. The arm facets are in two planes, that part outside the transverse ridge and containing the ligament pit and dorsal ligament fossae sloping more strongly from the horizontal than the part inside the transverse ridge. The brachials are many and of a great variety of types. On only a few specimens of one species were brachials found attached and then only the first primibrachs. It is impossible to associate most of the brachials with definite species and genera, but some may be classified on the basis of ornamentation. However, as these brachials correspond in size with associated calyces, and as all agree in gross characters with brachials specifically identifiable, there is no question that the brachials here described and illustrated belong to the Roveacrinidae.

The first primibrachs (pl. 71, figs. 4, 12; pl. 76, figs. 19, 27, 32) can generally be recognized by the proximal articulation surface, which must be in two planes to fit on the radial facet. $BrBr_1$ are short, rounded or angular in cross section, with or without a shallow groove on the inside (pl. 72, fig. 12) and with the distal surface sloping either inward toward the center of the calyx (pl. 76, fig. 19), or outward away from the calyx (pl. 71, fig. 4; pl. 76, fig. 27). The union between $BrBr_1$ and $BrBr_2$ is always a cryptosynarthy. $BrBr_2$ are generally longer than $BrBr_1$, rounded or angular in cross section, sloping inward or outward on the proximal surface to fit $BrBr_1$, and axial (pl. 71, fig. 5; pl. 76, figs. 30, 31, 33–36) or not axial (pl. 76, figs. 24, 46). Some $BrBr_2$ possess long serrated processes, others do not. The distal articulation surfaces on $BrBr_2$ are always muscular articulations. More varieties of $BrBr_2$ have been recognized than of any other brachial. Brachials beyond $BrBr_2$ are not known in order. Many have strong serrated distally pointing processes (pl. 71, figs. 7, 8; pl. 76, figs. 29, 40). Some have straight muscular articulation surfaces distally and proximally (pl. 71, figs. 7, 8; pl. 76, figs. 37, 39, 45), others have cryptosynarthial unions proximally (pl. 76, fig. 38) or distally (pl. 76, figs. 25, 29).

DEVELOPMENTAL TRENDS

With thousands of beautifully preserved fossils, all belonging to one small compact division and representing a comparatively short and relatively unbroken period of geological history, the opportunity for the study of developmental trends was unusual. While attempting to separate the Roveacrinidae into genera, species, and varieties, it seemed to me that at last I had come upon a group of organisms where intergradation was complete. There apparently was not a missing link in the entire series. Every variety graded into other varieties, species into other species, and even genera into other genera. When, however, I took the group of pictures for text figures 1–22 and started to arrange them along probable developmental lines I discovered that links were missing, that I had too few specimens from the Goodland and Kiamichi and nothing from below the Goodland, that I had a great variety of crinoids in the Duck Creek with no visible evidence of ancestors, and that one developmental line unaccountably ap-

peared in the Goodland and Kiamichi, completely skipped the Duck Creek, became the most abundant type in the Fort Worth, skipped the Denton, Weno, and Paw Paw, and again reappeared in great numbers in the Main Street and Grayson.

The oldest Roveacrinidae genera known are *Drepanocrinus* Jaekel and *Plotocrinus*, n. gen., from the Goodland limestone. These genera represent two subfamilies, the Drepanocrininae and the Roveacrininae, based on the presence or absence of a centrodorsal and upon the porosity of the skeletal material. The oldest record of the Roveacrinidae finds a group already well differentiated into two distinct developmental lines. It is possible to build a genealogical tree for the Roveacrinidae on either *Drepanocrinus* or *Plotocrinus*. However, considering the specialization of these two genera in the arm facets and modifications of the radials it seems probable that they were derived from a common ancestor.

Orthogonocrinus (text fig. 14) was derived from *Drepanocrinus* (text fig. 13) by the outer portion of the arm facet containing the dorsal ligament fossae and ligament pit turning down at a greater angle from the horizontal, giving a greater divergence in the slope of the facets on either side of the transverse ridge. This subfamily was stabilized, and no great evolutionary changes took place during the deposition of the Fredericksburg or Washita.

In the Roveacrininae, several lines of development are evident. On representatives of the genus *Plotocrinus* (text figs. 1, 2, 4–6) the calyx broadened out and became shallow, and the arm facets became very large. The ornamentation remained simple.

Another developmental line appeared suddenly in the Duck Creek and became greatly diversified in that formation. This group, represented by the genus *Poecilocrinus* (text figs. 3, 7, 11) is characterized by having the radial ridge bifurcate at about midheight and branch into a bowllike depression under the arm facets. Great numbers of small Duck Creek crinoids possess this character. Three recognizable groups were selected and given specific names (text figs. 3, 7, 11) but many of the crinoids in the Duck Creek belong somewhere in between these species rather than to them. Only one line of development here proved successful, giving rise to the beautiful and abundant *Poecilocrinus dispandus* (text fig. 8) of Fort Worth-Paw Paw age. Several varieties branched off this species (text figs. 9, 10), the last appearing in the Main Street.

A third line of development may have started with *Roveacrinus primitivus*, *R. distinctus*, or *R. pyramidalis*. I believe, as indicated in the text figures that *R. pyramidalis* was the ancestor. On this group the radial ridge is unbroken between the aboral pole and the proximal center of the radial facets. This type of ornamentation is present on *R. primitivus* and *R. distinctus* in the Goodland and Kiamichi, is unrepresented in the Duck Creek except on *R. pyramidalis* and species of *Plotocrinus*, reappears in great numbers as the widespread, abundant, and characteristic *R. latealatus* in the Fort Worth, again drops out of the picture during Denton, Weno, Paw Paw, and reappears in enormous numbers and great variety in the Main Street and Grayson, developing, during the Grayson, a great number of bizarre forms with spines, nodes, and flanges.

Neither the *Poecilocrinus* line nor the *Roveacrinus* line branched off *Plotocrinus* unless they did so in the Goodland or before. Both *Poecilocrinus* and *Roveacrinus* develop strongly pentagonal calyces with small arm facets that bear little resemblance to the broad, shallow calyces and large arm facets of *Plotocrinus*.

Discocrinus appears suddenly in the Duck Creek and drops out of the picture at the end of lower Fort Worth time, evidently giving rise to nothing new and leaving no trace of its ancestry.

LIFE HABITS

Jaekel (1921) considered *Drepanocrinus* a stemmed form with the proximal portion broken off. Ehrenberg (1929) stated that *Drepanocrinus* probably used the spikelike proximal for drilling in mud. Bather (1928) and Sieverts (1933) concluded that these crinoids were pelagic.

The Roveacrinidae were planktonic, floating passively, mouth down and arms pendent, driven along with the current with little if any power to determine their direction of movement. Several lines of evidence bear out this conclusion. First, although the skeleton is fairly massive, it is porous and in the lifetime of the crinoid was very light.

Second, forms that did not develop centrodorsals and thus remained unornamented (most of the ornamentation originated on the centrodorsals) had their skeletons lightened by resorption of the proximal portion (pl. 76, figs. 2–4, 9). On forms with centrodorsals either the ornamentation developed in such a way as to give horizontal flanges on both the calyx and the arms (pl. 73, figs. 11, 12, 14; pl. 76, figs. 30, 33–35, 37; text figure 1–22) or the calyces tended to become broad, shallow cups (pl. 71, fig. 11). The significance of the interfacet processes and the serrate processes on the arms is unknown.

TERMINOLOGY

In the preparation of the descriptions of the Roveacrinidae it has been found necessary to introduce a few new descriptive terms and to use some terms already in the literature with a slightly different meaning. For definitions of terms used but not defined in this paper, see A. H. Clark (1915, pp. 59–107).

Centrodorsal is defined by A. H. Clark (1915, p. 74) as

> The plate occupying the center of the aboral surface; it is usually large, discoidal, hemispherical or more or less conical, and bears numerous cirri on its edges, though never in the center.

Kirk (1911, p. 70) defines the centrodorsal as follows:

> The centrodorsal may be held to consist in its simplest form of the proximal columnal to which the infrabasals have been fused. Furthermore, centro-dorsal as here used may only apply to a cirriferous organ.

The structure enclosing the proximal cavity and growing up and over the aboral ends of the radials in the Roveacrinidae so closely resembles the centrodorsal of the comatulids in every way, except in the possession of cirri, that I have chosen to use the term centrodorsal in a wider sense rather than to coin a new term or to use the terms proximale or centrale.

Interfacet processes are the extensions of the sides of adjoining radials distally between the arm facets (pl. 71, figs. 21–24).

Radial facet support. In the Roveacrinidae the radials, or the radials and centrodorsals, are invariably ornamented and strengthened by a longitudinal thickening of the central part of the radial connecting the protruding proximal portion of the arm facet and the aboral pole. This longitudinal thickening is the base from which various types of ornamentation develop.

STRATIGRAPHIC DISTRIBUTION

Many of the species of the Lower Cretaceous crinoids of Texas are confined within formational boundaries. Exceptions to this are the ubiquitous *Drepanocrinus peracutus*, the long-ranged but rarely common *Orthogonocrinus apertus*, and the distinctive and fairly abundant *Roveacrinus pyramidalis*. *D. peracutus* ranges throughout the Lower Cretaceous and has every indication of being a well-established, stabilized species. I confidently expect that it will be found in formations older than Goodland and younger than Grayson. *O. apertus* and *R. pyramidalis* are, so far as is known, confined to the Washita group, but as I have crinoids from only a few localities in the Goodland and Kiamichi the present limits placed on the range of these species may be more because of a lack of information than from anything else.

Crinoids were obtained from only a few localities in the Goodland and Kiamichi, a circumstance that may account in some measure for the paucity of species repre-

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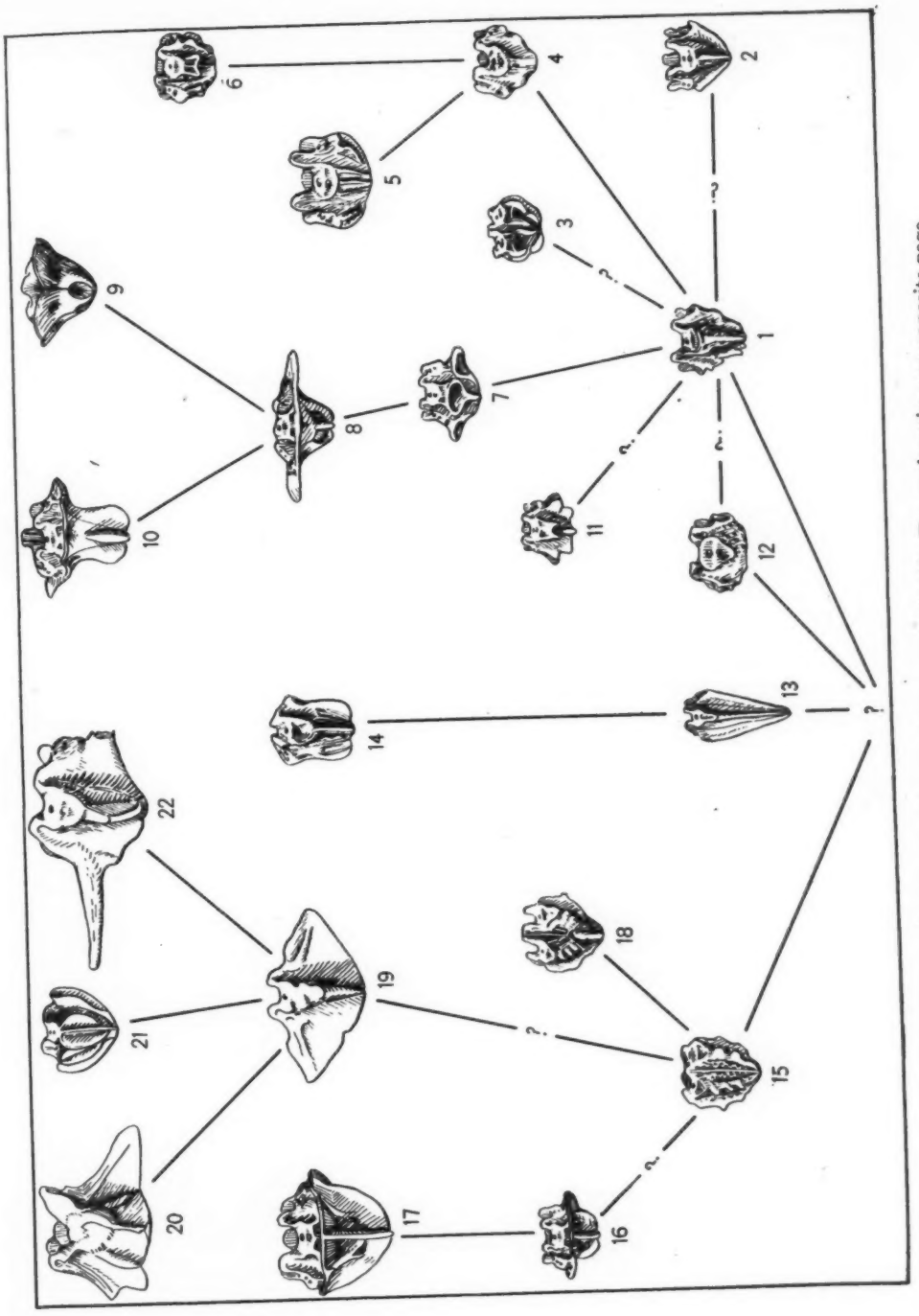
EXPLANATION OF FIGURES 1–22

FIG. *1*—*Plotocrinus primitivus* Peck, n. sp.
2—*Plotocrinus distinctus* Peck, n. sp.
3—*Poecilocrinus porcatus* Peck, n. sp.
4—*Plotocrinus inornatus* Peck, n. sp.
5—*Plotocrinus hemisphericus* Peck, n. sp.
6—*Plotocrinus modulatus* Peck, n. sp.
7—*Poecilocrinus pendulus* Peck, n. sp.
8—*Poecilocrinus dispandus* Peck, n. sp.
9—*Poecilocrinus dispandus explicatus* Peck, n. var.
10—*Poecilocrinus dispandus elongatus* Peck, n. var.
11—*Poecilocrinus spiculatus* Peck, n. sp.
12—*Discocrinus catastomus* Peck, n. sp.
13—*Drepanocrinus peracutus* Peck, n. sp.
14—*Orthogonocrinus apertus* Peck, n. sp.
15—*Roveacrinus pyramidalis* Peck, n. sp.
16—*Roveacrinus latealatus* Peck, n. sp.
17—*Roveacrinus signatus* Peck, n. sp.
18—*Roveacrinus euglypheus* Peck, n. sp.
19—*Roveacrinus pentagonus* Peck, n. sp.
20—*Roveacrinus spinalatus* Peck, n. sp.
21—*Roveacrinus multisinuatus* Peck, n. sp.
22—*Roveacrinus spinosus* Peck, n. sp.



FIGS. 1–22—Development of Lower Cretaceous crinoids. For explanation see opposite page.

sented. Some of the samples obtained did yield a considerable number of calyces, however, without showing any great variety. *P. distinctus* and *P. primitivus* are limited to these two formations. *P. distinctus* is easily recognized, quite distinctive, and is the best crinoid marker for the Goodland and Kiamichi.

The Duck Creek formation and the Grayson marl yielded more crinoids and a greater variety of crinoids than the other Lower Cretaceous formations. The Duck Creek assemblage is easily recognized and differentiated from other assemblages, but many individual forms are difficult to identify specifically. They are well preserved, abundant, and were evolving into new forms so rapidly that specific definitions are difficult to make. In general the large species of *Plotocrinus*, *P. hemisphericus* and *P. modulatus* are especially distinctive of Duck Creek. *Discocrinus* is easily recognized and closely restricted but not common. The genus *Poecilocrinus* is represented by three species that are easily identified when mature, well-developed, and well-preserved specimens are available, but they intergrade with each other to a considerable extent. The Duck Creek crinoids continue on into the lower Fort Worth formation, and in a few localities the two faunas intermingle.

The Fort Worth limestone is characterized by an abundance of crinoids but a lack of variety. The distinctive Fort Worth forms have extensive horizontal flanges. One species so adorned, *Roveacrinus latealatus*, is restricted to the Fort Worth.

The Denton, Weno, and Paw Paw formations are difficult to distinguish from each other and from the Fort Worth on the basis of crinoids. Nothing distinctive of, or restricted to, the Denton has been recognized. In the Weno representatives of *Poecilocrinus dispandus* are well developed and some samples yielded the distinctive *P. dispandus* var. *elongatus*. The Paw Paw has nothing that is distinctive.

The Main Street limestone and the Grayson marl bear closely related yet distinctive faunas. The Main Street marks the last occurrence of *Poecilocrinus dispandus*. *P. dispandus explicatus* is distinctive and easily recognized. *P. dispandus molestus* is not sufficiently widespread to be of value. The very abundant *Roveacrinus signatus* is present in both formations. The highly

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EXPLANATION OF PLATE 71

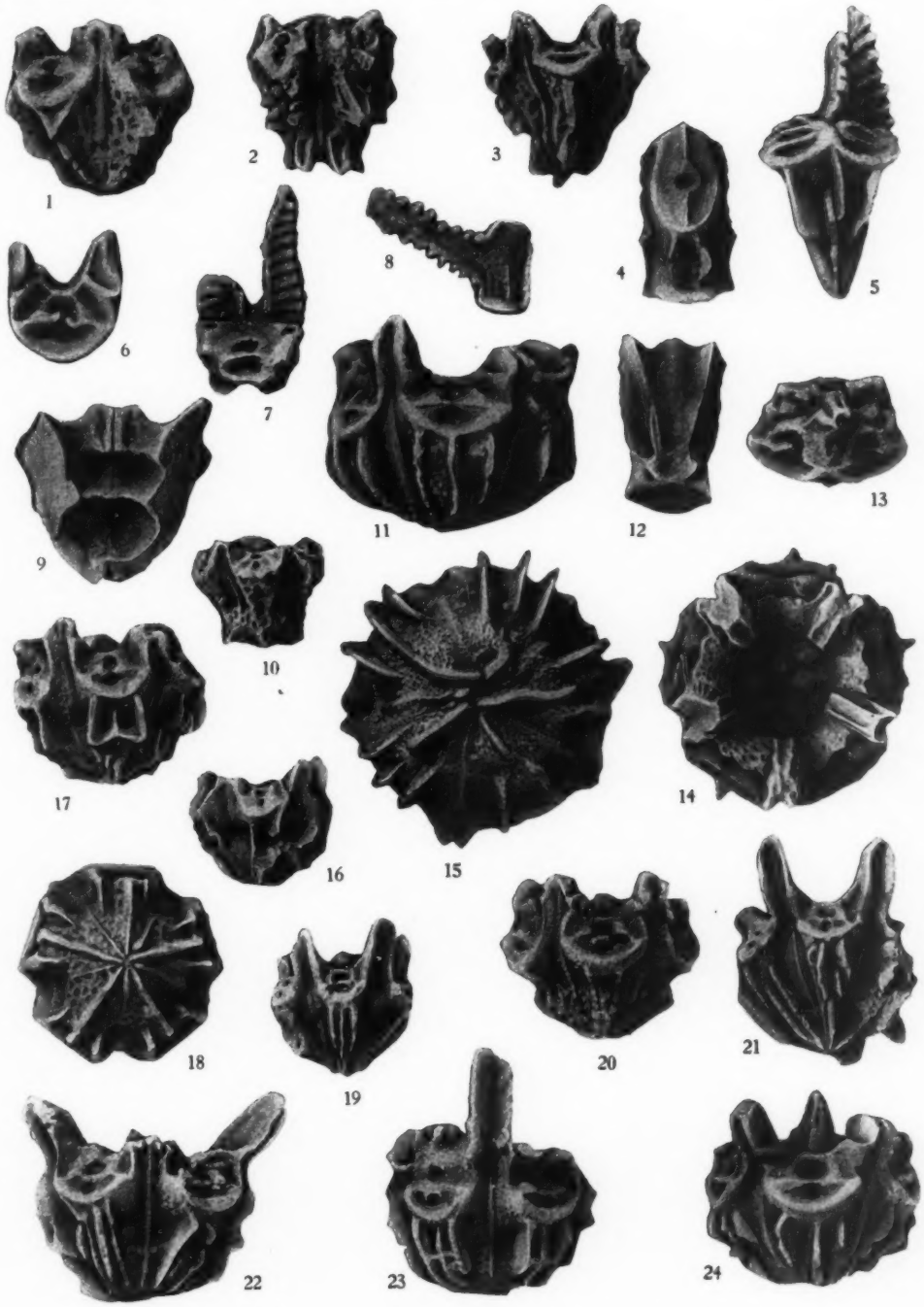
All figures ×18. All figured specimens in University of Missouri Collections. Two or more specimens that have the same catalog number are deposited in the same slide.

FIGS. *1–3—Plotocrinus primitivus* Peck, n. sp. *1*, Lateral view of paratype (E-9-1), Goodland HTL 169, sample 670. *2*, Lateral view of paratype (E-9-2) with radial flanges produced into nodes, Kiamichi HTL 104, sample 438. *3*, Lateral view of holotype (E-9-3), Goodland HTL 169, sample 670. (p. 470)

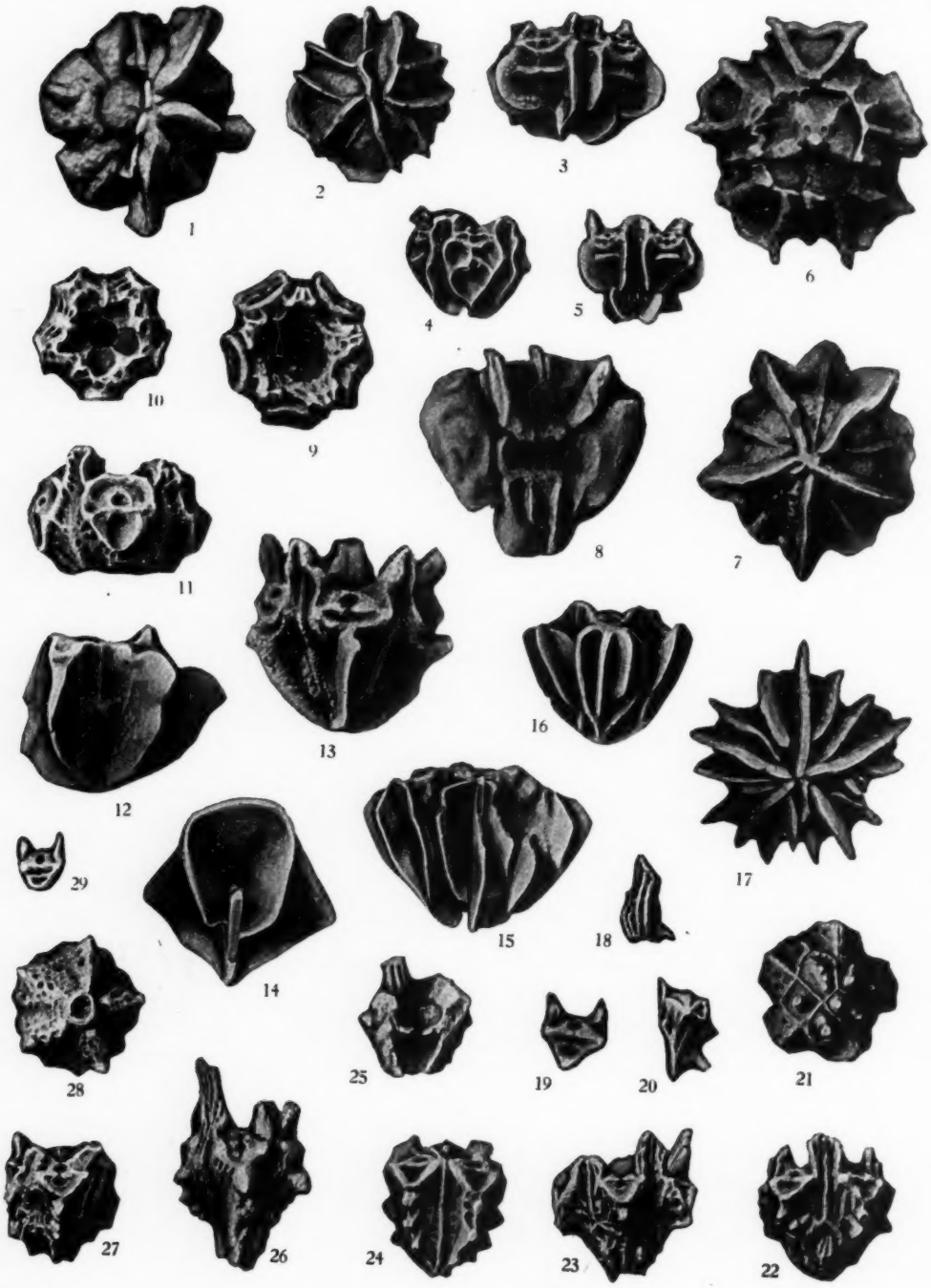
4, 5, 7–15, 24—Plotocrinus hemisphericus Peck, n. sp. *4*, Outer side of Br_1 showing sloping surface for cryptosynarthial union with Br_2, Duck Creek HTL 35, Peck sample. *5*, Outer side of Br_2 showing ornamentation and serrated processes, Duck Creek (E-9-4) HTL 57, Peck sample. *7*, Proximal surface of brachial (E-9-5) beyond Br_2 showing ligament pit, central canal and broken serrated process, Duck Creek HTL 35, Peck sample. *8*, Lateral view of brachial (E-9-5) beyond Br_2 showing serrated process, Duck Creek HTL 35, Peck sample. *9*, Section showing interior of two radials and centrodorsal, (E-10-1) Duck Creek HTL 35, Peck sample. *10*, Immature specimen (E-10-1) Duck Creek HTL 35, Peck sample. *11, 14*, Lateral and summit views of the holotype (E-10-2), Duck Creek HTL 35, Peck sample. *12*, Inner side of Br_1 (E-10-5) Duck Creek, HTL 35, Peck sample. *13*, Distal (upper) surface of Br_2 (E-11-1) showing attachment for two arms; Duck Creek HTL 57, Peck sample. *15*, Basal view of large paratype (E-10-3) showing maximum size of vertical flanges, Duck Creek HTL 34, sample 217. *24*, Lateral view of paratype (E-10-4), Duck Creek HTL 38, sample 224. (p. 469)

16–18, 23—Plotocrinus modulatus Peck, n. sp. *16*, Small paratype (E-11-2) showing growth of centrodorsal, Duck Creek HTL 57, Peck sample. *17, 18*, Lateral and basal views of holotype (E-11-3), Duck Creek HTL 57, sample 291. *23*, Paratype (E-11-4) illustrating long interfacet process—this process has been broken off since the photograph was taken—HTL 57, sample 291. (p. 470)

6, 19–22—Plotocrinus inornatus Peck, n. sp. *6*, Detail of arm facet of paratype (E-12-1), Duck Creek HTL 13, sample 114. *19, 21*. Small paratype (19) and somewhat mashed paratype, (E-11-5) showing long interfacet processes; lower Fort Worth HTL 28, sample 170. *20* small paratype (E-12-1) with large arm facets; Duck Creek HTL 13, sample 114. *22*, Holotype (E-12-2), Duck Creek HTL 57, sample 293. (p. 470)



Peck, Lower Cretaceous Crinoids



Peck, Lower Cretaceous Crinoids

ornate species of *Roveacrinus* are characteristic of the Grayson.

In summary, the Goodland and Kiamichi yield fairly large, simply ornamented species of *Plotocrinus*. The Duck Creek yields a distinctive fauna including *Discocrinus*, *Plotocrinus hemisphericus* and *P. modulatus* and large numbers of small, rather simply ornamented representatives of *Poecilocrinus*. *Roveacrinus latealatus* and numerous *Poecilocrinus dispandus* are distinctive in the Fort Worth. *P. dispandus elongatus* is a Weno form, and *P. dispandus explicatus* is characteristic of Main Street. The Grayson has many large highly ornamented representatives of *Roveacrinus*.

COLLECTING LOCALITIES

The crinoids described in this paper were obtained from collections made by Drs. A. R. and H. T. Loeblich of Tulane University and from collections made by me, which duplicates some of their collections. Only the Loeblich localities are listed here. A brief description of the locality is included with the discussion of those species whose types were selected from my collection.

The localities are listed consecutively under formation names. Only those localities and samples from which crinoids have been collected are listed.

Grayson marl

HTL[1] 1, samples 1–41. Grayson Bluff, a high southwest-facing bluff on Denton Creek, 2 miles east of the Fort Worth-Denton Highway, 3½ miles northeast of Roanoke, Denton County, Texas. The bluff can be seen from the highway to the south. Upper contact exposed, total thickness 60.5 feet, hand-level measurement. *Drepanocrinus peraculus, Orthogonocrinus apertus, Roveacrinus signatus, R. multisinuatus, R. pentagonus, R. spinosus, R. spinalatus, R. euglypheus.*

HTL 3, samples 46, 48. In a road cut, on the road between Grayson Bluff (HTL 1) and the Fort Worth-Denton highway, 2 miles east of the highway, Denton County, Texas. *Drepanocrinus peraculus, Roveacrinus signatus.*

HTL 5, samples 54–60. In a road cut and the creek bank of a tributary to Little Mineral Creek,

[1] HTL stands for H. T. Loeblich.

EXPLANATION OF PLATE 72

All figures ×18 except figure 6. All figured specimens in University of Missouri Collections. Two or more specimens that have the same catalog number are deposited in the same slide.

FIGS. *1, 7, 13—Plotocrinus distinctus* Peck, n. sp. *1*, Basal view of paratype (E-12-3) on which the left half of the centrodorsal has been broken away exposing the turned-in proximal portions of the radials and the thin partition (rosette) separating the body cavity from the proximal cavity. *7*, Basal view of paratype (E-12-3). *13*, Lateral view of holotype (E-12-4). All specimens from the Goodland HTL 73, sample 317. (p. 471)

2–6—Poecilocrinus porcatus Peck, n. sp. *2*, Base of paratype (E-12-5), Duck Creek HTL 35, Peck sample. *3*, Lateral view of holotype (E-13-1), lower Fort Worth HTL 77, sample 324. *4*, Paratype (E-13-2) showing variation in horizontal flange, Duck Creek HTL 35, Peck sample. *5*, Lateral view of paratype (E-13-3), lower Fort Worth HTL 77, sample 324. *6*, Basal view of paratype (E-13-2) ×32 from which the centrodorsal has been broken showing detail of proximal side of thin horizontal partition between body cavity and proximal cavity Duck Creek HTL 35, Peck sample. (p. 474)

9–11—Discocrinus catastomus Peck, n. sp. *9*, Summit view of holotype (E-13-4). *10, 11*, Basal and lateral views of paratypes (E-13-5), all specimens from lower Fort Worth HTL 28, Peck sample. (p. 474)

12—Roveacrinus pentagonus Peck, n. sp. Lateral view of paratype (E-14-1) with wide, thin vertical flanges, Grayson HTL 1, Peck sample. (p. 467)

8, 14–17—Roveacrinus multisinuatus Peck, n. sp. *8*, Natural section of paratype (E-14-2) showing outline of radials, proximal cavity, and massive centrodorsal almost completely covering outer portion of radials. *14*, Outer side of Br_2 (E-14-2), showing ornamentation. *15*, Lateral view of paratype (E-14-2). *16*, Lateral view of small paratype (E-14-2) with tertiary flanges (E-14-2). *17*, Basal view of holotype (E-14-3). All specimens from Grayson HTL 5, sample 58. (p. 466)

18–23—Roveacrinus euglypheus Peck, n. sp. *18*, Lateral view of Br_1. *20*, Lateral view of axial Br_2. *21*, Basal view of paratype showing ornamentation. *23*, Lateral view of paratype. All specimens (E-14-4) from Grayson HTL 1, Peck sample. *19*, Detail of arm facet of paratype (E-14-5) Grayson HTL 88, sample 358. *22*, Lateral view of holotype (E-15-1), Grayson HTL 94, sample 387. (p. 469)

24–29—Roveacrinus pyramidalis Peck, n. sp. *24*, Lateral view of holotype (E-15-2), Duck Creek HTL 13, sample 114. *25*, Natural section of paratype (E-15-3) showing interior, Main Street HTL 102, sample 418. *26*, Lateral view of paratype (E-15-3) showing width and strength of interfacet process, Main Street HTL 102, sample 418. *27*, Lateral view of paratype (E-15-4), Duck Creek HTL 35, Peck sample. *28*, Basal view of paratype (E-15-5) showing proximal opening to centrodorsal, Fort Worth HTL 39, sample 228. *29*, Detail of radical facet on paratype (E-16-1) from the Weno HTL 176, sample 686. (p. 468)

LOWER CRETACEOUS FORMATIONS OF TEXAS	DREPANOCRINUS PERACUTUS	ORTHOGONOCRINUS APERTUS	ROVEACRINUS PYRAMIDALIS	ROVEACRINUS EUGLYPHEUS	ROVEACRINUS LATEALATUS	ROVEACRINUS SIGNATUS	ROVEACRINUS PENTAGONUS	ROVEACRINUS SPINALATUS	ROVEACRINUS MULTISINUATUS	ROVEACRINUS SPINOSUS	PLOTOCRINUS HEMISPHERICUS	PLOTOCRINUS MODULATUS	PLOTOCRINUS INORNATUS	PLOTOCRINUS DISTINCTUS	PLOTOCRINUS PRIMITIVUS	POECILOCRINUS DISPANDUS	P. DISPANDUS VAR. ELONGATUS	P. DISPANDUS VAR. EXPLICATUS	P. DISPANDUS VAR. MOLESTUS	POECILOCRINUS PORCATUS	POECILOCRINUS PENDULUS	POECILOCRINUS SPICULATUS	DISCOCRINUS CATASTOMUS
GRAYSON	X	X	X	X		X	X	X	X	X													
MAIN STREET	X	X	X			X				X								X	X				
PAW PAW	X	X	X													X							
WENO	X	X	X													X	X						
DENTON	X	X	X													X							
FORT WORTH (UPPER)	X	X	X		X											X							
FORT WORTH (LOWER)	X	X	X		X						X		X			X				X	X	X	X
DUCK CREEK	X	X	X								X	X	X							X	X	X	X
KIAMICHI	X													X	X								
GOODLAND	X													X	X								

FIG. *23*—Distribution of crinoids in the Lower Cretaceous of Texas.

50 feet west of the road and north of the road cut, about ¼ mile south of Fink (locally called Georgetown) and 2½ miles north of Pottsboro, northwestern Grayson County, Texas. *Drepanocrinus peracutus, Roveacrinus signatus, R. multisinuatus, R. pentagonus, R. spinosus, R. spinalatus.*

HTL 8, sample 68. Three to 5½ feet above the Main Street limestone in a road cut on the south bank of Chuckwa Creek, on the west side of U. S. Highway 75, one mile north of Durant, in the NE. ¼ sec. 29, T. 6 S., R. 9 E., Bryan County, Oklahoma. *Drepanocrinus peracutus, Roveacrinus signatus, R. multisinuatus.*

HTL 31, samples 176, 180. Along the hillside and in the banks of a small creek, at the proposed road of 5th Avenue, between Nelson and Sheppard Streets, in the southeast part of the city of Denison, Grayson County, Texas. *Drepanocrinus peracutus, Roveacrinus signatus, R. multisinuatus, R. pentagonus.*

HTL 49, sample 265. Represents 1½ feet of nodular limestone at the base of the section exposed in a west-facing road cut on the east side of the Burleson-Alvarado Road, 1.7 miles southeast of the intersection with the Burleson-Cleburne Road, Johnson County, Texas. *Gryphea mucronata* is abundant in this zone and the specimens are usually large. *Drepanocrinus peracutus, Roveacrinus pentagonus.*

HTL 75, sample 322. Represents 5.5 feet of lower Grayson in the south-facing cliff of a small branch of Hickory Creek, on the east side of the Denton-Fort Worth Road, 5.2 miles by road from the southeast corner of the Denton County courthouse square in Denton, and 2.7 miles north of the railroad station in Argyle, Denton County, Texas. *Drepanocrinus peracutus, Roveacrinus signatus, R. euglypheus.*

HTL 87, sample 352. Represents 5.5 feet of lower Grayson in the middle of the exposure of Village Creek, where the stream bends about 100 yards south of the bridge on the Everman-Kennedale Road, 2 miles east of Everman, southeast of Fort Worth, Tarrant County, Texas. *Drepanocrinus peracutus.*

HTL 88, sample 358. Represents 5.5 feet of a grayish marl in lower Grayson, starting 18.5 feet below the top of the exposure in small, headwater branches of a tributary to Salado Creek, about 600 yards east of Highway 81, just east of a small branch road paralleling the highway 2.4 miles south of the bridge over Salado Creek, in the town of Salado, Bell County, Texas. The exposure faces west and can be seen from the highway. *Drepanocrinus peracutus, Roveacrinus signatus, R. euglypheus.*

HTL 90, samples 364–370. Consecutive samples, each representing 5.5 feet of section, starting at the base of the exposure on the west bank of Shoal Creek, just south of the bridge on 34th Street, and just north of a fault in Austin, Travis County, Texas. *Roveacrinus signatus, R. spinosus.*

HTL 94, sample 387. Represents the lower 5.5 feet of exposure in the bank of Barton Creek

where the Barton Springs Road crosses the creek, southwest of Austin, Travis County, Texas. *Drepanocrinus peracutus, Roveacrinus euglypheus.*

HTL 98, samples 404–405. Just downstream from the railroad bridge at South Bosque Station, on the west bank of the South Bosque River. From the lower 13 feet of Del Rio (Grayson equivalent). *Drepanocrinus peracutus, Roveacrinus signatus, R. pyramidalis.*

HTL 103, sample 423. Represents the upper 5.5 feet of exposure of yellow-gray marls in the steep northwest-facing slope, ¾ mile due east of Burleson, 0.2 mile northeast of the old Burleson-Alvarado Road, Johnson County, Texas. *Roveacrinus signatus, R. spinalatus.*

HTL 167, samples 666–667. In a small branch of Pepper Creek, south of the Belton-Temple Highway, Bell County, Texas, 1.4 miles east-northeast of the easternmost of the two underpasses of the highway under the Santa Fe Railroad (section in Univ. Texas Bull. 3016, pp. 53–54). *Roveacrinus spinalatus.*

Main Street limestone

HTL 36, samples 230–232. Cut along the road leading eastward to Grayson Bluff, from the Fort Worth-Denton Highway, 3.5 miles northeast of Roanoke, Grayson County, Texas. About 1 mile east of the highway and about ¾ mile west of Grayson Bluff. Woodbine sand covers the top of the outcrop. *Roveacrinus signatus, Poecilocrinus dispandus.*

HTL 55, sample 279. A 4-inch marl zone 4 feet above the base of the Main Street, in a road cut on the north side of the road, at the western edge of the Federal Narcotic Farm, southeast of Fort Worth, Tarrant County, Texas. The Main Street is composed of heavy beds of limestone with thin, yellow-gray marl zones interbedded. *Drepanocrinus peracutus, Roveacrinus pyramidalis, Poecilocrinus dispandus explicatus.*

HTL 102, samples 417, 418, lower Main Street. A road cut on the south side of the Godley-Cleburne Road, just uphill from the bridge across Noland River, 4.8 miles southeast of the Santa Fe Railroad Station in Godley, Johnson County, Texas. *Roveacrinus spinosus, R. pyramidalis, Poecilocrinus dispandus.*

HTL 177, sample 182. The top one foot of marl, just below uppermost limestone ledge, in a southeast-heading draw, on the east side of the Pottsboro-Fink Road, just south of the bridge over a tributary to Little Mineral Creek, about ¼ mile south of Fink (locally called Georgetown) and 2.5 miles north of Pottsboro, Grayson County, Texas. *Drepanocrinus peracutus, Roveacrinus signatus.*

Weno clay

HTL 46, samples 252, 253. Upper Weno. Exposure in the roadside ditch and road cut on the side of the hill along the west side of the Fort Worth-Burleson Highway, where it swings southward near the top of the hill, ½ mile southeast of where the Fort Worth-Everman Road turns from the Fort Worth-Burleson Highway, southeast of Fort Worth, Tarrant County, Texas. *Deprano-crinus peracutus, Orthogonocrinus apertus, Poelocrinus dispandus elongatus.*

HTL 47, sample 261. Lower Weno, 2–4¾ feet from the base of an 11-foot exposure of alternating limestones, light gray marls, and yellowish and brownish clays on the south bank of a tributary to Sycamore Creek, which was dammed to form Katy Lake, ½ mile east of and below the Katy Lake Dam, southeast of Fort Worth, Tarrant County, Texas. *Poecilocrinus dispandus.*

HTL 52, sample 271. Upper Weno. Represents 2 feet of alternating white marly limestone and thin grayish marly shale with some nodular limestone in a road cut and test pit on the south side of the Godley-Cleburne Road, at the top of a hill 0.2 mile west of Concord, a small town 4.4 miles southeast of Godley, Johnson County, Texas. *Roveacrinus pyramidalis, Poecilocrinus dispandus elongatus.*

HTL 65, sample 91. Represents 11 feet of lower Weno, upper 1 foot with two fossiliferous beds with chalky fossils and red iron concretions. The rest is of yellowish-blue clay to base of exposure. Taken at the top of the hill, on the west bank of the Washita River, due east of Woodville, in the NE. ¼ sec. 19, T. 7 S., R. 7 E., east of Woodville, Marshall County, Oklahoma. *Poecilocrinus dispandus.*

HTL 176, sample 686. Represents 10 feet of light yellow-gray marls interbedded with limestone in road cut on the Fort Worth-Mansfield Road, 0.3 mile south of the bridge where the highway crosses Sycamore Creek, Tarrant County, Texas. *Roveacrinus pyramidalis, Poecilocrinus dispandus.*

Denton clay

HTL 33, sample 194. On Armstrong Avenue, 0.5 mile north of the city standpipe, in the city of Denison, Grayson County, Texas. *Poecilocrinus dispandus.*

HTL 54, sample 274. Upper Denton. Represents 3.5 feet of yellowish and reddish clay, starting 9 feet below the top of the exposure along the steep west bank of the north fork of Noland's River, about 100 feet south of the bridge on the Godley-Joshua Road, 1.4 miles northeast of Godley, Johnson County, Texas. The upper two-thirds of the Denton is exposed. *Drepanocrinus peracutus, Poecilocrinus dispandus.*

HTL 80, samples 330, 331. Lower Denton. Road cut on the east side of U. S. Highway 77, 2.3 miles south of the south end of the bridge across Red River, where the highway bends southeast, in Cooke County, Texas. *Poecilocrinus dispandus.*

HTL 99, sample 410. Upper Denton. Represents 5.5 feet of section from base of exposure in ditch to base of limestone ledge at top, which marks base of Weno. Abundant *Gryphea washitaensis* juveniles. Taken in roadside ditch on east side of road leading south from Rio Vista, on the northeast corner where a less-traveled east branch road turns from the main south road, 1 mile south of the garage and filling station near the eastern edge of the town of Rio Vista, in southern Johnson County, Texas. *Drepanocrinus peracutus, Poecilocrinus dispandus.*

Fort Worth limestone

HTL 28, samples 170–172. Lower Fort Worth. On the north bank of Red River, south of U. S. Highway 75 bridge, on the east side of the bridge, in the SW. ¼ sec. 25, T. 8 S., R. 7 E., Bryan County, Oklahoma. *Drepanocrinus peracutus, Orthogonocrinus apertus, Roveacrinus pyramidalis, Plotocrinus hemisphericus, Plotocrinus inoratus, Poecilocrinus pendulus, P. porcatus, Discocrinus catastomus.*

HTL 39, samples 225–228. Creek bank, just north of the small concrete bridge where the road crosses a tributary of Hickory Creek, 1¼ miles northwest of Krum, Denton County, Texas. *Roveacrinus latealatus, Poecilocrinus dispandus.*

HTL 41, sample 237. Lower Fort Worth. Composite of the yellowish and grayish marly seams (4–8 inches thick) which alternate with 4–12 inch limestones on the southwest corner of the intersection of W. Berry and Merida Streets, at a small east-facing cliff that was the west bank of a small creek, 0.7 mile east of the southeast corner of the Texas Christian University campus, Fort Worth, Tarrant County, Texas. The total exposed thickness is 7 feet. *Roveacrinus latealatus Poecilocrinus dispandus.*

HTL 43, samples 245, 246. Upper Fort Worth. Taken 100 yards east of the underpass under the Frisco Railroad, in the banks of a small stream, on the Frisco road, which branches from the old Cleburne road crossing the Frisco tracks 0.3 mile south of Berry Street, in Fort Worth, Tarrant County, Texas. The locality is 1.9 mile from where the road branches. *Roveacrinus latealatus, Poecilocrinus dispandus.*

HTL 77, samples 324–327. Lower Fort Worth. In a stream bank on the south side of the stream, 0.9 mile south of the south end of the bridge over Red River, on U. S. Highway 77, and in a road cut on the east side of the highway about 200 feet north of the stream, in Cooke County, Texas. *Plotocrinus hemiphericus, Poecilocrinus spiculatus, P. porcatus, Discocrinus catastomus, Drepanocrinus peracutus.*

HTL 79, sample 329. Upper Fort Worth. Top 11 feet of section consisting of alternating yellowish-gray marls and nodular limestones with numerous *Gryphea, Pecten, Ostrea americana* and echinoids in the road cut on the east side of U. S. Highway 77, 1.6 miles south of the south end of the bridge across Red River, in Cooke County, Texas. *Orthogonocrinus apertus, Roveacrinus latealatus.*

HTL 84, sample 348. Marl breaks between limestone ledges in the road cut on the northeast corner of the intersection of Frazier and Lowden Streets, in Fort Worth, Tarrant County, Texas. *Orthogonocrinus apertus, Poecilocrinus dispandus.*

Duck Creek formation

HTL 13, samples 112–122. West bank of the Red River, in the SW. ¼ sec. 22, T. 8 S., R. 2 E., on the southwest side of Horseshoe Bend, Love County, Oklahoma. *Drepanocrinus peracutus, Orthogonocrinus apertus, Roveacrinus pyramidalis, Plotocrinus hemisphericus, P. modulatus, P. inornatus, Poecilocrinus spiculatus, P. pendulus, P. porcatus, Discocrinus catastomus.*

HTL 27, sample 165. About 20 feet above the base of the Duck Creek in the cut of the Missouri, Kansas, and Texas Railroad, which is above and to the west of Duck Creek, east of Highway 75, 2¾ miles north of Denison, Grayson County, Texas. *Drepanocrinus peracutus, Roveacrinus pyramidalis, Plotocrinus modulatus, Discocrinus catastomus.*

HTL 34, samples 210–218. Type locality of the Duck Creek formation, in the banks of Duck Creek and in the railroad cut where the St. Louis and San Francisco Railroad comes close to the creek, 2¾ miles north of Denison, on Highway 75, and east of the highway, Grayson County, Texas. *Drepanocrinus peracutus, Orthogonocrinus apertus, Plotocrinus hemisphericus, P. modulatus, P. inoratus, Poecilocrinus spiculatus, P. porcatus, Discocrinus catastomus.*

HTL 35, samples 277, 278. East side of road cut just inside the entrance to Forest Park, 0.4 mile straight north of the northeast corner of the Texas Christian University campus, in Fort Worth, Tarrant County, Texas. The Duck Creek forms a 12-foot bluff. *Drepanocrinus peracutus, Roveacrinus pyramidalis, Plotocrinus hemisphericus, P. inornatus, Poecilocrinus spiculatus, P. pendulus, P. porcatus, Discocrinus catastomus.*

HTL 38, sample 224. Upper Duck Creek. A low, north-facing cliff forming the south bank of Hickory Creek, 150 feet north of the road, where the road leading northwest from Krum to Trinity Farms crosses Hickory Creek, 8 miles northwest of Krum, Denton County, Texas. The sample represents 3 feet of alternating limestones and shaly marls at the base of the exposed section. *Drepanocrinus peracutus, Plotocrinus hemisphericus, P. inornatus, Poecilocrinus pendulus, Discocrinus catastomus.*

HTL 42, samples 238, 239. Lower Duck Creek. High east-facing cliff on the west bank of Ammonite Creek, about 500 feet south of the road marking the northern boundary of the Municipal Golf Course, and in about the center of the golf course southwest of Fort Worth, Tarrant County, Texas. The bluff is about 10 feet high, and there are thin marl seams between heavy limestone ledges about 1.5 feet thick. *Drepanocrinus peracutus, Orthogonocrinus apertus, Plotocrinus hemisphericus, P. modulatus, P. inornatus, Discocrinus catastomus.*

HTL 57, samples 290–296. Road cut on the east side of U. S. Highway 77, just south of the bridge across Red River, Cooke County, Texas. *Drepanocrinus peracutus, Orthogonocrinus apertus, Roveacrinus pyramidalis, Plotocrinus hemisphericus, P. modulatus, P. inornatus, Poecilocrinus spiculatus, P. pendulus, Discocrinus catastomus.*

HTL 60, samples 300–303. Lower Duck Creek. Low north-facing cliff on the south bank of a small creek, a short distance north of the road, 0.1 mile east of the bridge which crosses the creek, 0.9 mile east of Fink (locally called Georgetown) in Grayson County, Texas. The formation is composed of alternating heavy limestones and thin marls, and is an excellent locality for *Desmo-*

ceras brazoensis. Drepanocrinus peracutus, Plotocrinus modulatus, Poecilocrinus spiculatus, Discocrinus catastomus.

HTL 76, sample 323. About 2 feet of calcareous marl in a west-facing road cut, on the east side of U. S. Highway 77, 3.2 miles south of Marietta, in the NW. ¼ sec. 5, T. 8 S., R. 2 E., Love County, Oklahoma, and 20.2 miles north of the courthouse square at Gainesville, Texas. *Orthogonocrinus apertus.*

HTL 104, samples 440–460. High north-facing slope on the south bank of Red River, cleared by excavation at the site of Denison Dam, north of Denison, Grayson County, Texas. The slope is now covered and grassed over. *Drepanocrinus peracutus, Orthogonocrinus apertus, Plotocrinus hemisphericus, P. modulatus, P. inornatus, Poecilocrinus spiculatus, Discocrinus catastomus.*

Kiamichi formation

HTL 104, sample 438. Locality described under Duck Creek limestone. Uppermost 2 feet of Kiamichi, consisting of thin shaly layers betweeen ledges of *Gryphea* conglomerate. *Drepanocrinus perculus, Plotocrinus primitivus, P. distinctus.*

HTL 170, samples 676, 677. Upper 10 feet of Kiamichi brown marl in a deep road cut on the Stove Foundry Road, just north of the new Texas and Pacific Railroad shops, Fort Worth, Texas, *Drepanocrinus peracutus, Plotocrinus primitivus.*

Goodland limestone

HTL 73, sample 317. About 4 feet of section, 10 feet below the top of the bluff, in a hard light-brown marl, just below massive, fossiliferous white limestone in the north side of the old Foundry Road, 3.8 miles west of Montgomery Street at Cragin Knob, in Fort Worth, Tarrant County, Texas. Total exposed 21 feet. Collected by Frank E. Lozo. *Drepanocrinus peracutus, Plotocrinus primitivus, P. distinctus.*

HTL 169, samples 670–672. Low bluff on the east bank of the North Fork of Mary's Creek, at concrete bridge on the Fort Worth-Weatherford Highway, 11½ miles west of Fort Worth, Tarrant County, Texas. *Drepanocrinus peraculus, Plotocrinus primitivus, P. distinctus.*

DESCRIPTION OF NEW FAMILIES, GENERA, AND SPECIES

Family ROVEACRINIDAE, n. fam.

Small stemless pelagic monocyclic Inadunata with calyces composed of five radials only, or five radials with ornamented noncirriferous centrodorsals. The sides of adjoining radials extend distally to form prominent processes between the arm facets. The calyx cavity is divided into two parts, a body cavity and a proximal cavity, by a horizontal partition corresponding to the rosette of the comatulids. Arms five or ten, the division, when present, on the second brachial.

Distribution.—Cretaceous of Europe and North America.

Discussion.—In 1908 Douglas described the genus *Roveacrinus* with two species and one variety from the Cretaceous chalk of England. In 1921 Jaekel described the genus *Drepanocrinus* from the Cretaceous of Germany with one species. Sieverts, in 1932, redescribed *Drepanocrinus* Jaekel in considerable detail and illustrated several unattached brachials. In 1933 Sieverts discussed *Drepanocrinus* Jaekel as a synonym of *Roveacrinus* Douglas and described three species occurring in the Cretaceous of Germany. For reasons detailed under the generic descriptions I believe both *Roveacrinus* and *Drepanocrinus* are valid genera and in this paper I am proposing four additional genera to be included in the family.

The systematic relationships of these distinctive little pelagic crinoids have caused considerable discussion. Douglas observed "rounded or oval thickenings" on the proximal portions of the calyces, and these with "radials with an external keel and downward prologations" (p. 358) led him to believe that *Roveacrinus* was allied to *Extracrinus.*

Jaekel (1921) interpreted the broken proximal portion of the calyces of his specimens of *Drepanocrinus* as stem facets and considered the basal circlets as fused. These evidences, combined with an interpretation of unattached brachials associated with the calyces, led him to refer *Drepanocrinus* to the Rhizocrinidae and to consider it closely allied to *Bathycrinus.*

Bather (1928) stated that *Roveacrinus*, with the long processes between the radial facets, might be related to *Phyllocrinus.*

Sieverts (1932) gave an excellent and detailed discussion of the morphology, systematic position, and life habits of *Drepanocrinus* Jaekel. She based her conclusions concerning the systematic position on unattached brachials and followed Jaekel in referring *Drepanocrinus* to the Rhizocrinidae.

In 1933 Sieverts again discussed these crinoids. This time she considered *Drepanocrinus* a synonym for *Roveacrinus* and stated that representatives of the genus were unquestionably pelagic. In this paper and again in Biese and Sieverts-Doreck (1937) *Roveacrinus* is referred to the Rhizocrinidae

on the evidence of unattached brachials.

The genera *Roveacrinus* Douglas and *Drepanocrinus* Jaekel, together with the four new genera proposed in this paper, possess in common a set of characters found in no other representatives of the Crinoidea. These characters are: (1) long processes formed by the growth of sides of adjoining radials, here called *interfacet processes*, (2) large, well-developed radial facets, (3) two cavities, a body cavity and a proximal cavity, separated by a horizontal partition resembling and probably homologous with the rosette of the comatulids, (4) most representatives possess a well-developed, highly ornamented noncirriferous centrodorsal enclosing the proximal portion of the radials.

Phyllocrinus possesses the long interfacet processes, but has neither the large arm facets nor the centrodorsal, and is an attached form.

The large arm facets, the centrodorsals, and the two cavities separated by the rosette are all characters possessed by comatulids. The arms, either single or branching on the second brachial, resemble those of the comatulids as much as they resemble those of any other group of crinoids. The Roveacrinidae differ from the comatulids only in that the centrodorsal fails to develop cirri. The centrodorsal develops a radial type of ornamentation that is lacking in the true comatulids. The Roveacrinidae evidently branched off the main line of comatulids in Jurassic or early Cretaceous and lived only through the Cretaceous. In the Cretaceous they were farther advanced toward simplification and specialization than most true comatulids in that they had lost any trace of basals.

Among the crinoid calyces here referred to the Roveacrinidae are two general types of structure. On one type the radials are greatly elongated but retain their identities as individual radials throughout the length of the calyx. This fact is shown by crushed and broken specimens where the line of weakness and breakage is almost always along the interradial sutures. The calyx walls of these specimens are smooth and compact. A few specimens show some evidence of a network of fine ridges, but the skeletal structure is not coarsely porous. These forms are of the same general type as *Drepanocrinus sessilis* Jaekel, *Roveacrinus communis* Douglas, and *Roveacrinus westfalicus* Sieverts.

The other type of calyx has short radials that meet proximally or have the proximal ends overgrown by noncirriferous centrodorsals. The skeletal structure is coarsely porous. On some of the early representatives the presence of a centrodorsal is difficult to demonstrate, but it is clearly evident on specimens of Duck Creek age or younger. The relationship can always be verified by the coarsely porous calyx wall. These forms are of the same general type as *Roveacrinus alatus* Douglas.

These two groups are sufficiently distinct to justify and make desirable the division of the Roveacrinidae into two subfamilies, the Drepanocrininae and the Roveacrininae.

Subfamily DREPANOCRININAE, n. subfam.

Roveacrinidae with calyces composed of elongated radials only. No centrodorsal. Skeletal structure compact, not coarsely porous.

Genus DREPANOCRINUS Jaekel, 1921, emend.

Small, elongate, slender crinoid crowns with slender undivided arms and conical calyces composed of five elongate, triangular radials. Radial facets occupying most of the distal surfaces of the radials, triangular or semicircular in shape, sloping outward, the angle from horizontal a little greater outside than inside the transverse ridge. Dorsal ligament fossae and inarticular ligament fossae well developed, muscular fossae narrow, and partially excavated in sides of interfacet processes. Arms simple, not branching, the distal surface of Br_1 sloping inward and joined to Br_2 by cryptosynarthy. Calyx smooth and compact, not coarsely porous. Some specimens covered with fine network of ridges.

Genotype.—*Drepanocrinus sessilis* Jaekel from Cretaceous of Germany.

Distribution.—Upper Cretaceous of England and Germany; Lower Cretaceous of Texas.

Discussion.—This genus was described by Jaekel in 1921 and redescribed and discussed in detail by Sieverts in 1932. In 1933

Sieverts considered *Drepanocrinus* a synonym of *Roveacrinus* Douglas.

Jaekel, although treating his new genus with great brevity, did illustrate several unattached brachials. The first brachial (Jaekel's figures C-E) slopes inward on the distal surface. The second brachial (Jaekel's figures F-G) is axillary but also slopes inward on the proximal surface. It is impossible for Jaekel's Br_2 to fit his Br_1. Sieverts (1932) illustrates several unattached brachials that, she states, belongs to *Drepanocrinus*. The $BrBr_1$ figured by Sieverts slope outward on the distal surface and would fit either the $BrBr_2$ figured by Sieverts or by Jaekel.

Among the crinoids from the Lower Cretaceous of Texas that otherwise correspond in structure to *Drepanocrinus sessilis* Jaekel are three specimens with $BrBr_1$ attached (pl. 76, figs. 9, 28). In each case the distal surface of $BrBr_1$ slopes inward as in Jaekel's figures C-E and would not fit with either Jaekel's or Sievert's illustrations of $BrBr_2$. The only $BrBr_2$ in the Lower Cretaceous that will fit on this type of $BrBr_1$ are not axillary, so it is assumed that *Drepanocrinus* had undivided arms.

Roveacrinus Douglas, according to Bather (see discussion under that genus) and to Sieverts (1932, 1933), has axillary $BrBr_2$. *Roveacrinus alatus* Douglas, the genotype, also has a coarsely porous calyx (Sieverts, 1933, p. 55; 1932, fig. 6a, p. 609), and a slightly to well developed centrodorsal.

Although Jaekel was evidently unaware of Douglas' paper when he described *Drepanocrinus* I believe there is valid distinction between the two genera.

DREPANOCRINUS PERACUTUS Peck, n. sp.
Plate 76, figures 9–22, 26, 28

Calyx small, a mature individual attaining a maximum height of about 2 mm.; conical in lateral view, strongly pentagonal in end view. The proximal end, when uninjured, forms a sharp point; the distal end, when uninjured, possesses five fairly strong interfacet processes.

Radials triangular longitudinally and in cross section, pointed below and partially truncated by arm facet above, the triangular cross section the result of a longitudinal ridge extending the full length of the radial and supporting the outside portion of the arm facet. Radials of different length, only two forming the proximal point, the other three pinching out proximally against the two longer radials near the base. Radials on some specimens covered by fine anastomosing ridges.

Radial facets elongate, occupying about four-fifths of distal surface of radials, sloping outward, the part outside the transverse ridge sloping about 60° from horizontal, the part inside the transverse ridge sloping at about 40°. Dorsal ligament fossae large, elongate parallel to long axis of calyx and situated mostly on radial longitudinal ridge. Interarticular ligament fossae large, forming a crescent around the central canal, not differentiated into separate fossae, bordered distally by calyx interior and laterally along distal part by low but definite ridge that forms inside border of the muscular fossae. Muscular fossae narrow, deep, paralleling adjoining interfacet processes.

Arms slender and undivided. $BrBr_1$ short and boot-shaped, with distal surfaces sloping inward. $BrBr_2$ about the same length as $BrBr_1$ and somewhat triangular with a proximal face sloping outward to fit inward sloping faces of $BrBr_1$. Brachials beyond $BrBr_2$ not known in order. The most common type is as long as the combined lengths of $BrBr_1$ and $BrBr_2$, excavated slightly throughout its length on exterior sides, and possessing two pairs of fairly strong, distally pointed processes. One pair of processes is located at midlength, the other at the distal end. The brachials beyond Br_2 have open grooves distal to the centrally situated processes. Proximal to these processes and along the entire length of $BrBr_2$ the inner surface is flat or slightly concave, making a cross section of the brachials in this area triangular. $BrBr_1$ concave on the interior. Br_1 and Br_2 are joined by a cryptosynarthy. All other unions by muscular articulation.

The thin, delicate horizontal partition (rosette) on the interior of the calyx is about one-fourth the calyx length down from summit, and on most specimens has a round excavation on the proximal side (pl. 76, figs. 22) in the center. The radials are much thicker above the partition than below.

The smallest representatives of this species are almost disk-shaped with five short

thin radials surmounted on the distal side by small facets (pl. 76, fig. 12). The proximal side is flattened, and the radials do not meet in the center. On the outside of the proximal parts of the radials are small cylindrical growths. With an increase in size the radials elongate proximally, meeting in the center to form a closed cavity; the cylindrical growths elongate with the radials and form the radial ridges; the arm facets elongate dorsoventrally; and the radials thicken greatly above the horizontal partition. The body cavity becomes deeper with growth but does not increase in circumference. On many specimens the radials are extremely thin proximally and do not meet along their lateral edges, probably indicating resorbtion. On some specimens the radial ridge broadens about the center of the calyx into bulbous forms. These swellings are never present on larger specimens.

Types.—Holotype and figured paratypes in the University of Missouri Collections. Unfigured paratypes, Loeblich Collection no. 1002, 1003; U. S. National Museum.

Occurrence.—Common throughout the Lower Cretaceous of Texas from the Goodland to the Grayson.

Discussion.—Although this species is common and many specimens were collected, only a few of the larger individuals are uninjured proximally. This is due in part to the thinness and fragility of the proximal parts of the radials. The species can be identified from a small portion of the calyx by the pentagonal outline and elongate arm facets. European species belonging to this genus have semicircular arm facets.

Genus ORTHOGONOCRINUS[2] Peck, n. gen.

Small rectangular Drepanocrininae composed of five elongate radials with well-developed arm facets occupying most of the distal surface and part of the sides, the facets making a right angle turn at the transverse ridge. Inarticular ligament fossae, muscular fossae, and central canal located on horizontal distal surface of the radials, and large dorsal ligament fossae and ligament pit excavated in side of radials. Skeletal material smooth, compact, not porous, Arms unknown.

Genotype.—*O. apertus* Peck, n. sp., from the Lower Cretaceous of Texas.

Discussion.—*Orthogonocrinus* is closely related to and probably developed from *Drepanocrinus* by the proximal portion of the arm facet turning down and becoming excavated in the sides of the radials. The two genera agree in all other details.

ORTHOGONOCRINUS APERTUS Peck, n. sp.
Plate 76, figures 2–8

Calyx small, a mature individual attaining a maximum height of about 2 mm., and a maximum diameter of 1.4 mm.; rectangular in lateral view with proximal portion of calyx broken away or resorbed, and pentagonal in end view with each radial ornamented by a narrow, sharp longitudinal ridge.

Central canal fairly large, located near the outer border of the summit of the calyx. Interarticular ligament fossae large, excavated below the general surface of the facet,

[2] ὀρθόγωνος—rectangular.

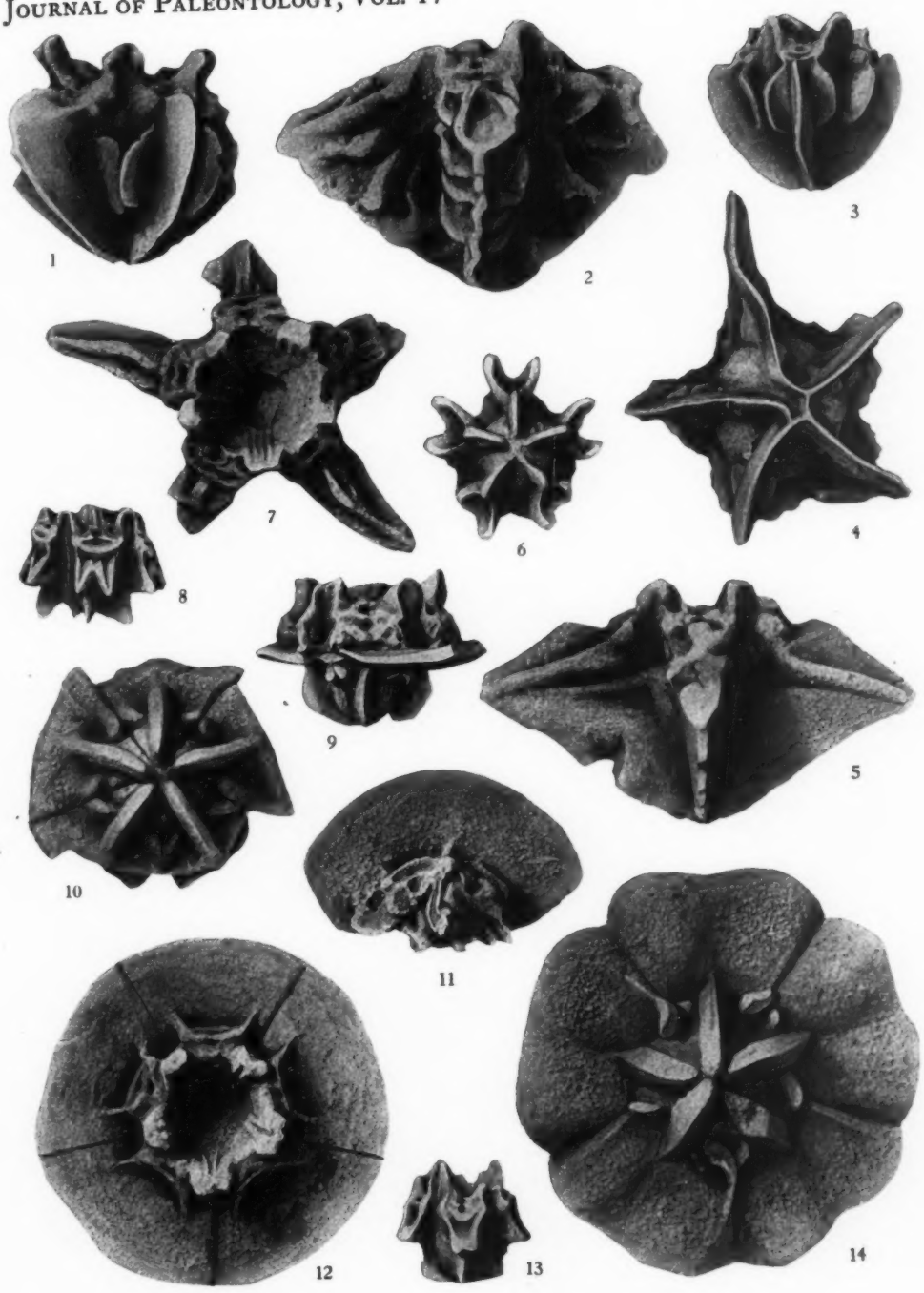
EXPLANATION OF PLATE 73

All figures ×18. All figured specimens in University of Missouri Collections. Two or more specimens that have the same catalog number are deposited in the same slide.

FIGS. *1–5, 7—Roveacrinus pentagonus* Peck, n. sp. *1, 3*, Lateral views of paratypes (E-16-2) with wide, thin flanges and small secondary flanges. *2*, Large, corrugated paratype (E-16-2) with secondary growths on the main flanges. *4*, Basal view of paratype (E-16-2) showing flanges and large centrodorsal. *5, 7*, Lateral and summit view of holotype (E-16-3). All specimens from the Grayson HTL 5, sample 59. (p. 467)

6, 8, 13—Poecilocrinus spiculatus Peck, n. sp. *6*, Basal view of holotype (E-16-4), lower Fort Worth HTL 77, sample 324. *8, 13*, Lateral views of paratypes (E-16-5), Duck Creek HTL 57, Peck sample. (p. 472)

9–12, 14—Roveacrinus latealatus Peck, n. sp. *9*, Lateral view of paratype (E-17-1) with the horizontal flange broken off, Fort Worth HTL 39, sample 227. *10*, Basal view of paratype (E-17-2) showing centrodorsal, Fort Worth HTL 39, sample 228. *11*, Distal surface of Br_2 (E-17-2) showing articulation facets and wide horizontal flange, Fort Worth HTL 39, sample 228. *12*, Summit view of paratype (E-17-1), Fort Worth HTL 39, sample 227. *14*, Basal view of holotype (E-17-3) Fort Worth HTL 39, sample 225. (p. 468)



Peck, Lower Cretaceous Crinoids

Peck, Lower Cretaceous Crinoids

elongate parallel to the interfacet processes, bordered distally and laterally along most of their length by prominent crescentric ridges that connect the interfacet processes. Muscular fossae small, elongate parallel to interfacet process. Dorsal ligament fossae large, deeply excavated into side of radials, crescentric in shape, bordered by a raised rim. Ligament pit deep.

Calyx cavity small, the wide, thin interfacet processes extending into the cavity and almost meeting in the center. Walls thick above the horizontal partition but thin and poorly developed proximal to it.

Types.—Holotype and figured paratypes in the University of Missouri Collections. Unfigured paratypes, Loeblich Collection no. 1000, 1001; U. S. National Museum.

Occurrence.—Duck Creek to Grayson. Holotype from Duck Creek HTL 57, Peck sample.

Discussion.—This is a widely distributed but not particularly common species. It ranges from Duck Creek to Grayson but is more common in the Duck Creek than any other formation. The rectangular shape, sharp radial ridges, flat summit, and the right-angled turn in the arm facets make it an easily recognized species..

Subfamily ROVEACRININAE, n. subfam.

Roveacrinidae with calyces composed of short radials and noncirriferous centrodorsals. Skeletal structure coarsely porous. Arms five or ten, the division, when present, on Br_2.

This subfamily is readily divided into three genera on the basis of form and size of the calyx, size and shape of the arm facets, and the type of radial ornamentation. Representatives of this group are abundant in the Lower Cretaceous of Texas and, for the most part, have short vertical ranges.

Genus ROVEACRINUS Douglas, 1908
emend. Sieverts, 1933, Peck 1942

Small to medium size Roveacrininae with radial ornamentation consisting primarily of five flanges connecting the proximal centers of the arm facets with the aboral pole. The arm facets are small, semicircular, about as wide as long and separated by a distance equal to their own width. Arms probably 10, branching on $BrBr_2$, ornamentation similar to that of the calyx. $BrBr_1$ and $BrBr_2$ joined by cryptosynarthy.

Genotype.—*Roveacrinus alatus* Douglas from the Cretaceous of England.

Discussion.—Douglas described *Roveacrinus* in 1908 with two species and one variety. As he failed to designate a genotype the first described species, *R. alatus*, is here designated. On the two drawings of *R. alatus*, Douglas lists the oral view as "restored," and it is probable that at least a little interpretation has gone into the second drawing. Douglas' description leaves much to be desired. He mentions neither brachials nor ornamentation of the calyx other than the prominent radial spines. Additional information concerning Douglas' specimens is furnished by a letter written by Dr. F. A.

EXPLANATION OF PLATE 74

All figures ×18. All figured specimens in University of Missouri Collections. Two or more specimens with the same number are deposited in the same slide.

FIGS. *1–5, 11–14—Roveacrinus signatus* Peck, n. sp. *1*, Basal view of almost mature paratype (E-17-4) from Grayson HTL 3, sample 45. *2*, Natural section showing interior of two radials and proximal cavity of paratype (E-17-5), Grayson HTL 1, Peck sample. *3, 5, 14*, Basal, lateral and summit views of holotype (E-18-1) Grayson HTL 1, Peck sample. *4, 13*, Basal views of paratypes (E-18-2) Main Street HTL 36, sample 232. *11*, Basal view of small paratype (E-17-5) Grayson HTL 1, Peck sample. *12*, Summit view of paratype (E-19-1) with horizontal flange uninjured on upper and left side, Grayson HTL 87, sample 352. *11, 13, 4, 1, 3*, are basal views representing growth stages. (p. 466)

6, 7, 9—Roveacrinus spinosus Peck, n. sp. *6*, Lateral view of paratype (E-18-3) from the Grayson HTL 1, Peck sample. *7*, Lateral view of paratype (E-18-4) from Main Street, HTL 51, sample 270. *9*, Lateral view of holotype (E-18-5) from Grayson HTL 1, Peck sample. (p. 467)

8, 10—Roveacrinus spinalatus Peck, n. sp. *8*, Lateral view of holotype (E-19-2) from Grayson HTL 1, Peck sample. The near radial facet and spiniferous flange are broken away exposing the centrodorsal. *10*, Small paratype (E-19-3) from Grayson HTL 1, Peck sample, showing start of spiniferous flange. (p. 467)

Bather to Mr. Rowe, collector of the crinoids, under the date of August 23, 1908 and communicated to me by Mr. James Wright of Edinburgh, Scotland. Evidently Mr. Rowe had sent the type specimens to Dr. Bather for examination. Dr. Bather wrote:

His (Douglas') descriptions seem correct as far as they go but I have a good deal to add. In particular I have found the brachials which he could not find. There are first primibrachs, second primibrachs, which are axillary, and a secundibrach.

It is impossible to tell from Douglas' description and illustrations if the calyx of *R. alatus* is porous. However, Sieverts (1933) described *R. alatus* as covered with a coarse network of ridges and her illustration (1932) shows a wall structure similar to the forms here referred to *Roveacrinus*. The proximal swelling shown by Sieverts suggests the presence of a centrodorsal. As nearly as I can determine from Douglas' and Sieverts' descriptions and figures, *R. alatus* closely resembles *Roveacrinus spinosus* or *Roveacrinus spinalatus* described below from the Grayson formation.

The genus *Roveacrinus* is distinguished by the prominent and persistent radially situated flange connecting the arm facet and the aboral pole. The flange is always present and identifiable even though many modifications of specific value are introduced. *Roveacrinus* never attains the size, the hemispherical shape, nor the large arm facets of *Plotocrinus*, n. gen. *Poecilocrinus*, n. gen. has a radial flange that bifurcates at midheight.

ROVEACRINUS SIGNATUS Peck, n. sp.
Plate 74, figures 1–5, 11–14

Calyces medium to large, somewhat hourglass-shaped with large, globular centrodorsals set off from the conical cups formed by the radials by prominent constrictions. Radial facet supports consist of five radial flanges that distally give rise to small horizontally directed disks. With increase in size of the calyx the flanges increase in strength and the disks grow larger, meeting disks from adjoining rays and forming an almost horizontal flange around the upper part of the calyx.

Types.—Holotype and figured paratypes in the University of Missouri Collections. Unfigured paratypes, Loeblich Collection no. 1008; U.S. National Museum.

Occurrence.—Confined to the Main Street and Grayson formations. Holotype from Grayson HTL 1.

Discussion.—This is the most abundant and most widely distributed of the Grayson-Main Street crinoids. It closely resembles *Roveacrinus latealatus* from the Fort Worth and probably is a descendant of that species. Unfortunately, as neither of these species is represented in the Denton-Weno-Paw Paw formations, it is impossible to prove the relationship. *R. signatus* is larger than *R. latealatus*, has the radial flanges more strongly developed, and always has a lesser proportional development of the horizontal flange around the distal part of the calyx. The globular centrodorsal is always prominent on *R. latealatus* but is largely covered by radial facet supports on representatives of *R. signatus*. All size stages may be found in both species. Figures, 1, 3, 11, 13, 14, on plate 74, represent growth stages of *R. signatus*.

ROVEACRINUS MULTISINUATUS Peck, n. sp.
Plate 72 figures 8, 14–17

Calyx medium to large for the genus, somewhat hourglass-shaped with a prominent constriction setting off the large globular centrodorsal from the conical cup formed by the radials. On mature and well-preserved individuals the excessive development of the radial facet support obscures all of the calyx except the oral surface.

Radial facet support consists of five prominent radial flanges connecting the aboral pole and the proximal part of the radial facet with flanges branching off on each side just above the aboral pole and extending along the entire length distally. The secondary flanges grow laterally and slightly outward, meeting those from adjoining rays and turning strongly outward. Lateral flanges from adjoining rays never coalesce or lose their identity. On some specimens additional small flanges branch off the upper half of the main flange.

Arm facets small and semicircular. Arms normal for the genus with the same type of ornamentation as the calyx.

Types.—Holotype and figured paratypes in the University of Missouri Collections. Unfigured paratypes, Loeblich Collection no. 1016; U. S. National Museum.

Occurrence.—Confined to the Grayson formation. Types from Grayson HTL 5.

Discussion.—*R. multisinuatus* is exceptionally abundant at HTL 5 and 8. The species is easily distinguished by the large number of vertical flanges of about equal strength that extend almost the entire length of the calyx. *Roveacrinus pentagonus* also develops lateral flanges, but the central flange is much stronger than the lateral.

ROVEACRINUS PENTAGONUS Peck, n. sp.
Plate 72, figure 12; plate 73, figures 1–5,7

Calyx medium to large for the genus with large globular centrodorsal. Radial facet supports consist of wide thin vertical flanges that are either (1) simple and undivided, (2) thickened near the summit and tending to be a spine, or (3) have small lateral flanges branching off the upper part. Some of the largest individuals have irregular ridges and small flanges all along the main flange.

Types.—Holotype and figured paratypes in the University of Missouri Collections. Unfigured paratypes, Loeblich Collection no. 1015; U. S. National Museum.

Occurrence.—Confined to the Grayson formation. Types from Grayson HTL 5.

Discussion.—*R. pentagonus* has the basic architecture of most of the species and varieties in the Grayson formation and evidently is the form from which many of the other species branched. In this species I am including comparatively small forms with wide, perfectly simple flanges such as plate 72, figure 12; specimens with simple flanges that bear small lateral flanges such as plate 73, figures 1, 3, and large forms with the flange thickened near the top and along the sides, plate 73, figure 5. From the specimens illustrated it would seem practical to distinguish at least varieties among the types referred to this species. However, they intergrade in such a way that it is difficult to separate them.

R. pentagonus is exceptionally abundant in localities HTL 5 and 8.

ROVEACRINUS SPINOSUS Peck, n. sp.
Plate 74, figures 6,7,9; plate 76, figures 37, 39

Medium-sized to large calyces with large globular centrodorsals. The flanges forming the radial facet supports are produced into long, almost horizontally directed spines, and the brachials carry the same type of ornamentation.

Types.—Holotype and figured paratypes in the University of Missouri Collections. Unfigured paratypes, Loeblich Collection, no. 1014; U. S. National Museum.

Occurrence.—Grayson and Main Street. Holotype from Grayson HTL 1.

Discussion.—Representatives of this species with spines complete and unbroken are rare, and even fragmental representatives are not common. There is considerable variation within this species in the form and location of the spines and the development of the radial flanges. The spines may be located just under the arm facet (pl. 74, fig. 7) at about midheight (pl. 74, fig. 6); or below midheight (pl. 74, fig. 9). Radial flanges proximal to the spines may or may not be well developed.

This species probably developed from *R. pentagonus*. The two species agree in all details except the modifications having to do with the radial facet support.

ROVEACRINUS SPINALATUS Peck, n. sp.
Plate 74, figures 8, 10

Calyces medium to large with large centrodorsals. Radial facet supports consist of long proximally directed spines originating under the radial facets. The entire proximal sides of the spines are joined to the lower part of the centrodorsals by thin flanges. Very large individuals develop ridges on the flanges.

Types.—Holotype and figured paratype in the University of Missouri Collection. Unfigured paratypes, Loeblich Collection no. 1013; U. S. National Museum.

Occurrence.—Confined to the Grayson formation. Types from Grayson HTL 1.

Discussion.—*R. spinalatus* differs from the other large species of the genus in the Grayson only in ornamentation. This type

of ornamentation is probably derived from the thin flanges of *R. pentagonus*. *R. spinalatus* and *R. spinosus* are closely related.

ROVEACRINUS LATEALATUS Peck, n. sp.

Plate 73, figures 9–12, 14; plate 76, figure 1

Calyces medium to small for the genus with fairly large globular centrodorsals. Radial facet supports consist of radial flanges connecting the proximal portion of the radial facet with the aboral pole. Along the distal part of the main flanges small curved supplementary flanges branch off, growing laterally and outward and maintaining distal connections with the main flange, producing horizontally directed disks that continue their growth, meeting disks from adjoining rays to form a wide horizontal flange around the upper portion of the calyx just below the arm facets.

The axillary $BrBr_2$ also bear wide horizontal flanges.

Types.—Holotype and figured paratypes in the University of Missouri Collections. Unfigured paratypes, Loeblich Collection no. 1009; U. S. National Museum.

Occurrence.—Fort Worth formation. Types from Fort Worth HTL 39.

Discussion.—Superficially, *R. latealatus* closely resembles *Poecilocrinus dispandus*, from the Fort Worth to Paw Paw formations. The two species cannot be differentiated from an oral view. From an aboral or side view it is readily evident that on *R. latealatus* the main radial flange continues all the way from the aboral pole to the proximal portion of the radial facet. On representatives of *Poecilocrinus dispandus* the flanges fork about midheight of the calyx.

R. latealatus is probably the ancestor of *R. signatus* of the Main Street limestone and Grayson marl, although representatives of this line of development have not been found in intervening formations. *R. latealatus* is smaller than *R. signatus*, the horizontal flange has a greater proportional development and extends more nearly at right angles to the calyx.

R. latealatus appears to be an excellent marker for the Fort Worth limestone, but I expect to find, eventually, this species or closely related forms in the Denton and Weno.

ROVEACRINUS PYRAMIDALIS Peck, n. sp.

Plate 72, figures 24–29

Calyx small, about 1 mm. in height exclusive of interfacet processes, pyramidal in shape. Interfacet processes about as long as calyx is tall and about half as wide as the arm facets. Radial facet supports consist of fairly strong vertical flanges or ridges that may be smooth and unbroken but are more often serrated or produced into spines or nodes directed proximally. Calyx coarsely porous and covered with network of fairly coarse ridges.

Radial facets comparatively small, somewhat angular in shape, the portion outside the transverse ridge and enclosing the ligament pit and dorsal ligament fossae forming an isosceles triangle with the transverse ridge as the base. Dorsal ligament fossae well developed, most of them situated proximal to the ligament pit. Interarticular ligament fossae fairly large. Arms unknown.

Types.—Holotype and figured paratypes in the University of Missouri Collections. Unfigured paratypes, Loeblich Collection no. 1005, 1006; U. S. National Museum.

Occurrence.—Duck Creek to Grayson. Most common in Duck Creek and Fort Worth. Holotype from Duck Creek HTL 13.

Discussion.—This is the longest-ranged species of *Roveacrinus* in the Lower Cretaceous of Texas. It is easily recognized and identified by the pyramidal shape, coarsely porous calyx, and angular arm facets with most of the dorsal ligament fossae proximal to the ligament pit.

The shape of the radial facets and the position of the dorsal ligament fossae might be considered justification for establishing a separate genus to contain *R. pyramidalis* and *R. euglypheus*. The arm facets of these two species are intermediate in position between those of *Drepanocrinus peracutus* and other species referred to *Roveacrinus*. In all other characters *R. pyramidalis* and *R. euglypheus* agree with other species here referred to *Roveacrinus*, and there appears to be little advantage to be gained in referring them to another genus.

The proximal opening on the specimen illustrated on plate 72, figure 28, suggests a

stem facet. It should be noted, however, that this is an opening into the centrodorsal cavity, and that the centrodorsal is well developed. Such openings are found on several species at various stages of growth.

ROVEACRINUS EUGLYPHEUS Peck, n. sp.
Plate 72, figures 18–23

Calyx small, subconical, attaining a maximum diameter of about 1 mm., broader than long. Interfacet processes long and broad, the width equal to the width of the arm facet. Calyx ornamented by strong radial ridges immediately under the arm facets and low but prominent ridges starting on the interfacet processes and extending aborally along the interradial sutures. Just below midheight of the calyx the interradial ridges bifurcate, each branch extending laterally and aborally to just below the radial ridge where, joined by a branch from the adjoining interradial suture, it extends vertically to the aboral pole in a radial position. Directly below the bifurcation in an interradial position are five nodes or spines that extend laterally and aborally. Calyx very porous and covered with a coarse network of ridges.

Radial facets angular, pentagonal in outline, the portion outside the tranverse ridge and enclosing the ligament pit and dorsal ligament fossae an isosceles triangle with the transverse ridge as the base. Dorsal ligament fossae well developed, most of its surface proximal to ligament pit. Inarticular ligament fossae fairly large, excavated below the general surface of facet, not meeting inside the central canal.

Arms small, delicate, coarsely porous.

Types.—Holotype and figured paratypes in the University of Missouri Collections. Unfigured paratypes, Loeblich Collection no. 1007; U. S. National Museum.

Occurrence.—Confined to the Grayson. Holotype from Grayson HTL 94.

Discussion.—This is a particularly well marked species. It differs from all associated calyces in that the interradial ridges bifurcate just below midheight and continue to the aboral pole in a radial position.

This species is essentially *R. pyramidalis* with the aboral portion (the centrodorsal) revolved through an angle of 36°, thus placing the lower part of the radial ridge in an interradial position. Examination of this species at once suggests the possibility of radials and basals and the immediate reaction is that here is an ancestral form from which other Roveacrinidae may have developed. Two facts preclude this possibility. *R. euglypheus* is confined to the Grayson, the highest formation in the Lower Cretaceous of Texas, and in crushed specimens the radials separate along the interradial suture to the point of bifurcation, but below this point there is no regular zone of weakness apparent. Evidently this is a terminal form on which ornamentation alone has revolved, and the proximal portion consists of a centrodorsal.

Genus PLOTOCRINUS[3] Peck, n. gen.

Fairly large hemispherical Roveacrininae with large arm facets, well-developed centrodorsals and radial ornamentation consisting of either simple vertical flanges or simple flanges flanked on either side along their distal half by additional flanges. No spines, wings, or horizontal flanges developed. Arms large and massive, branching on $BrBr_2$. All known brachials above $BrBr_2$ possess strong, distally pointed processes on the inner side. Union of $BrBr_1$ and $BrBr_2$ by cryptosynarthy, other unions by muscular articulation or cryptosynarthies.

Genotype.—*Plotocrinus hemisphericus* Peck, n. sp. from the Lower Cretaceous of Texas.

Discussion.—The outstanding characters of this genus are the large calyces, hemispherical shape, large arm facets, and the simplicity of radial ornamentation. This is the oldest known genus of the Roveacrininae but there is no evidence indicating that it is the form from which all the others evolved.

PLOTOCRINUS HEMISPHERICUS Peck, n. sp.
Plate 71, figures 4–5, 7–15, 24

Mature calyx hemispherical, maximum height and diameter about 2.2 mm., typically wider than high. Interfacet processes well developed, their length almost equalling the maximum height of the calyx. Interradial sutures marked by a thickening of

[3] πλωτὸς—floating.

adjoining radials to produce a low ridge extending to the aboral pole of the centrodorsal, the thickening extending internally within the centrodorsal as partitions. Entire calyx porous and covered with network of small ridges.

Radial facet supports consist of single, low ridges or flanges radiating from the aboral pole and flanked along the distal two-thirds by additional flanges. The three flanges located on each radial have additional material between them, causing a thickening under, and giving apparent support to, the protruding proximal portion of the arm facets. The flanges are comparatively small on immature individuals but increase in size proportionately with the growth of the specimens.

Arm facets semicircular on small specimens, broadening at the transverse ridge with growth until on large individuals the facet approaches a circular outline. Central canal and ligament pit large, occupying almost one-third of the facet. Arms typical for the genus, branching on $BrBr_2$ and with serrated interior processes exceptionally well developed.

On immature specimens there is a constriction marking the contact of the centrodorsal with the proximal part of the radials but with growth this constriction is filled, and it is difficult to determine the contact.

Types.— Holotype and figured paratypes in the University of Missouri Collection. Unfigured paratypes, Loeblich Collection no. 1018; U. S. National Museum.

Occurrence.—Duck Creek and lower Fort Worth formations. Holotype from Duck Creek HTL 35.

Discussion.—*P. hemisphericus* is a characteristic Duck Creek species. It is easily recognized by the large size, hemispherical shape, and the exceptionally large arm facets. *P. hemisphericus* intergrades with *Plotocrinus inornatus*, and it is difficult to determine to which species some specimens should be referred.

PLOTOCRINUS MODULATUS Peck, n. sp.
Plate 71, figures 16–18, 23

Lateral flanges of radial facet support well developed, and distal part of central flange reduced or absent, forming an almost square boxlike structure directly under the radial facet. Centrodorsal exceptionally well developed and contact with radials marked by constriction.

Types.—Holotype and figured paratypes in the University of Missouri Collections. Unfigured paratypes, Loeblich Collection no. 1017; U. S. National Museum.

Occurrence.—Restricted to the Duck Creek. Types from Duck Creek HTL 57.

Discussion.—This is a well-marked and easily recognized species of *Plotocrinus* that is restricted to the Duck Creek. It often occurs in the same section with *P. hemisphericus* or *P. inornatus*, but is seldom found in the same samples.

PLOTOCRINUS INORNATUS Peck, n. sp.
Plate 71, figures 6, 19–22

Calyces small, conical, with large arm facets. Radial facet supports consist of radial thickening under the arm facet that may or may not manifest itself as longitudinal ridges. Calyx usually deeply indented between facet supports, pentagonal from basal view.

Types.—Holotype and figured paratypes in the University of Missouri Collections. Unfigured paratypes, Loeblich Collection no. 1019; U. S. National Museum.

Occurrence.—Duck Creek and lower Fort Worth formations. Holotype from Duck Creek HTL 57.

Discussion.—This is probably the species from which *P. hemisphericus* and *P. modulatus* evolved. *P. inornatus* grades into both species.

PLOTOCRINUS PRIMITIVUS Peck, n. sp.
Plate 71, figures 1–3

Calyces medium to small, pyramidal in shape with corners of the pyramids formed by radial facet supports, coarsely porous and covered with network of fairly coarse ridges. Interfacet processes low, stubby, forming about one-fifth the total calyx height. Radial facet supports consist of single ridges that bifurcate just below the arm facet, each ridge connecting with the outside proximal portion of the arm facet. The main ridges of the supports are smooth, serrated, or produced into proximally directed spines.

Types.—Holotype and figured paratypes in the University of Missouri Collections.

Unfigured paratypes, Loeblich Collection no. 1026; U. S. National Museum.

Occurrence.—Goodland and Kiamichi. Holotype from Goodland HTL. 169.

Discussion.—Some representatives of this species differ from specimens of *Roveacrinus pyramidalis* only in the shape and size of the arm facets and the location of the dorsal ligament fossae. Large, rapidly expanding representatives of *P. primitivus* closely resemble *P. inornatus* and *P. distinctus*.

P. primitivus may be the ancestor of *P. distinctus*, *P. inornatus*, and perhaps of the genera *Roveacrinus* and *Poecilocrinus*. The tendency for the radial facet support to bifurcate just under the arm facet could lead into the dominant ornamentation of the divided ridge in the genus *Poecilocrinus*. A restriction of the tendency of this ridge to bifurcate might allow this form to give rise to *Roveacrinus*, on which the dominant ornamentation is a single undivided ridge.

PLOTOCRINUS DISTINCTUS Peck, n. sp.
Plate 72, figures 1, 7, 13

Calyx conical, of medium size, maximum height and diameter about 1.7 mm., most specimens a little wider than high. Interfacet processes low, stubby, forming about one-fifth the total calyx height. Radial ornamentation consists of well-developed single undivided flanges that extend distally beyond the proximal edge of the facet and form small hooklike projections. Calyx covered with network of coarse to fine ridges. Arms unknown.

Types.—Holotype and figured paratypes in the University of Missouri Collections. Unfigured paratypes, Loeblich Collection no. 1025; U. S. National Museum Collection.

Occurrence.—Goodland and Kiamichi. Types from Goodland HTL 73.

Discussion—P. distinctus is an easily recognized form and is an excellent marker for Goodland and Kiamichi.

Genus POECILOCRINUS[4] Peck, n. gen.

Roveacrininae on which the radial ornamentation consists of a single flange that bifurcates at midheight or below, each branch connecting with the outside proximal portion of the arm facet to form an enclosed, more or less circular depression under the arm facet, the depression on most specimens remaining hollow but being occasionally bisected by a vertical flange of secondary origin.

Genotype.—*Poecilocrinus dispandus* Peck, n. sp., from the Lower Cretaceous of Texas.

Discussion.—This genus differs from *Roveacrinus* only in the bifurcation of the radial flange. On representatives of *Roveacrinus* the flange connects the aboral pole with the proximal portion of the arm facet. The range of *Poecilocrinus* is Duck Creek to Main Street.

POECILOCRINUS DISPANDUS Peck, n. sp.
Plate 75, figures 1, 2, 6, 8, 12

Calyx of medium size, the radials forming a shallow conical cup resting within a globular centrodorsal. Radial facet supports well developed, the distal portions developing into a very large horizontal flange located just under the arm facets.

Types.—Holotype and figured paratypes in the University of Missouri Collections. Unfigured paratypes, Loeblich Collection no. 1010; U. S. National Museum Collection.

Occurrence.—Fort Worth to Main Street. Holotype from upper Fort Worth HTL 43.

Discussion.—R. dispandus is the most abundant and widespread species of crinoids in the upper Fort Worth, Denton, Weno, and Paw Paw. It is rivaled in abundance in the upper Fort Worth by *Roveacrinus latealatus* and is far surpassed in abundance in the Main Street by *Roveacrinus signatus*. *P. dispandus* cannot be differentiated from either *R. latealatus* or *R. signatus* orally but in an aboral or lateral view it can readily be noted that on *P. dispandus* the main flange of the radial facet support divides and on the representative of *R. latealatus* and *R. signatus* it continues unbroken to the arm facet.

P. dispandus probably developed from *P. pendulus* in the Duck Creek.

POECILOCRINUS DISPANDUS ELONGATUS Peck, n. var.
Plate 75, figure 7

On calyces referred to this variety the lateral extensions of the radial facet supports coalesce and extend downward, forming an

[4] ποικίλος—ornamented.

elongate cylindrical support for the horizontal flange. On some specimens the proximal radial flanges extend outward past the general surface of the cylinder.

Types.—Holotype in the University of Missouri Collections. Unfigured paratypes, Loeblich Collection no. 1011; U. S. National Museum Collection.

Occurrence.—Confined to two localities in the Weno. Holotype from Weno HTL 46.

POECILOCRINUS DISPANDUS EXPLICATUS
Peck, n. var.
Plate 75, figures 11, 14

On calyces referred to this variety the large horizontally directed flange extends laterally and upward, making the calyces in lateral view appear as cones flaring at the top. The cavity within the radial facet supports, just below the arm facet, is greatly reduced, and the supports extend down and almost completely cover the globular centrodorsals.

Types.—Holotype in the University of Missouri Collection. Paratypes, Loeblich Collection no. 1012; U. S. National Museum Collection.

Occurrence.—Main Street formation. Holotype from Main Street HTL 55.

POECILOCRINUS DISPANDUS MOLESTUS
Peck, n. var.
Plate 75, figure 4

This variety is larger than *P. dispandus*, s. s., and possesses a secondary vertical flange bisecting the circular depression below the arm facet.

Types.—Holotype in the University of Missouri Collection.

Occurrence.—Main Street at underpass of Santa Fe Railroad on the Belton-Temple Highway just north of Belton, Bell County, Texas. The sample was taken just west of the underpass and about 18 inches above the level of the road. This is below the zone of abundant *Exogyra arietina* and is listed by Adkins and Arick (1930) as Main Street.

Discussion.—This variety is easily distinguished from *Roveacrinus signatus* in that the vertical flange on *R. signatus* is a single unit all the way up. This variety was found only in the one locality.

POECILOCRINUS SPICULATUS
Peck, n. sp.
Plate 73, figures 6, 8, 13

Calyx somewhat rectangular in outline, of medium size with maximum height about 1 mm. and maximum diameter slightly greater. Each radial facet support consists of five strong flanges that extend horizontally from the aboral pole, turn upward at a right angle and bifurcate below midheight, taking part in the formation of a circular bowllike support for the proximal portion of the arm facet. The circular support may maintain a smooth, even ridge, the distal portion may be produced into a long, narrow platform, or the distal outside edges may be produced into spines. Any extension of the distal part

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EXPLANATION OF PLATE 75

All figures ×18. All figured specimens in the University of Missouri Collections. Two or more specimens with the same number are deposited in the same slide.

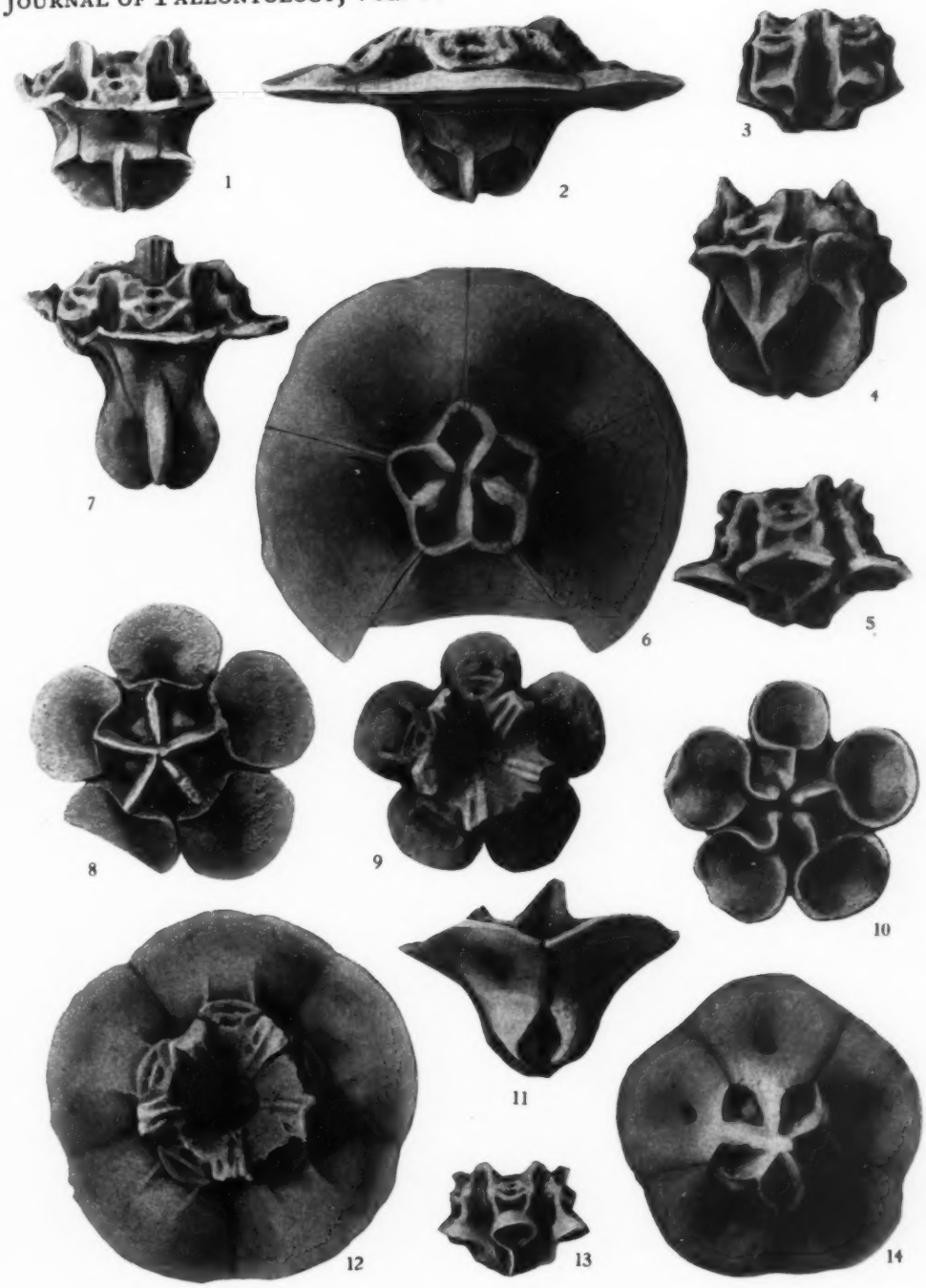
FIGS. *1, 2, 6, 8, 12—Poecilocrinus dispandus* Peck, n. sp. *1*, Lateral view of small paratype (E-19-4) with horizontal flange broken away, Weno HTL 176, sample 686. *2*, Lateral view of holotype (E-19-5), upper Fort Worth HTL 43, sample 145. *6*, Basal view of paratype (E-20-1) from Denton HTL 99, sample 410. *8*, Lateral view of small paratype (E-19-4) from Weno HTL 176, sample 686. *12*, Summit view of paratype (E-19-4) Weno HTL 176, sample 686. (p. 471)

3, 5, 9, 10, 13—Poecilocrinus pendulus Peck, n. sp. *3*, Small paratype (E-20-2) from Duck Creek HTL 57, sample 291. *5, 9, 10*, Lateral, summit, and basal views of holotype (E-20-3) lower Fort Worth HTL 28, Peck sample. *13*, Lateral view of small paratype (E-20-4) from Duck Creek HTL 57, sample 295. (p. 474)

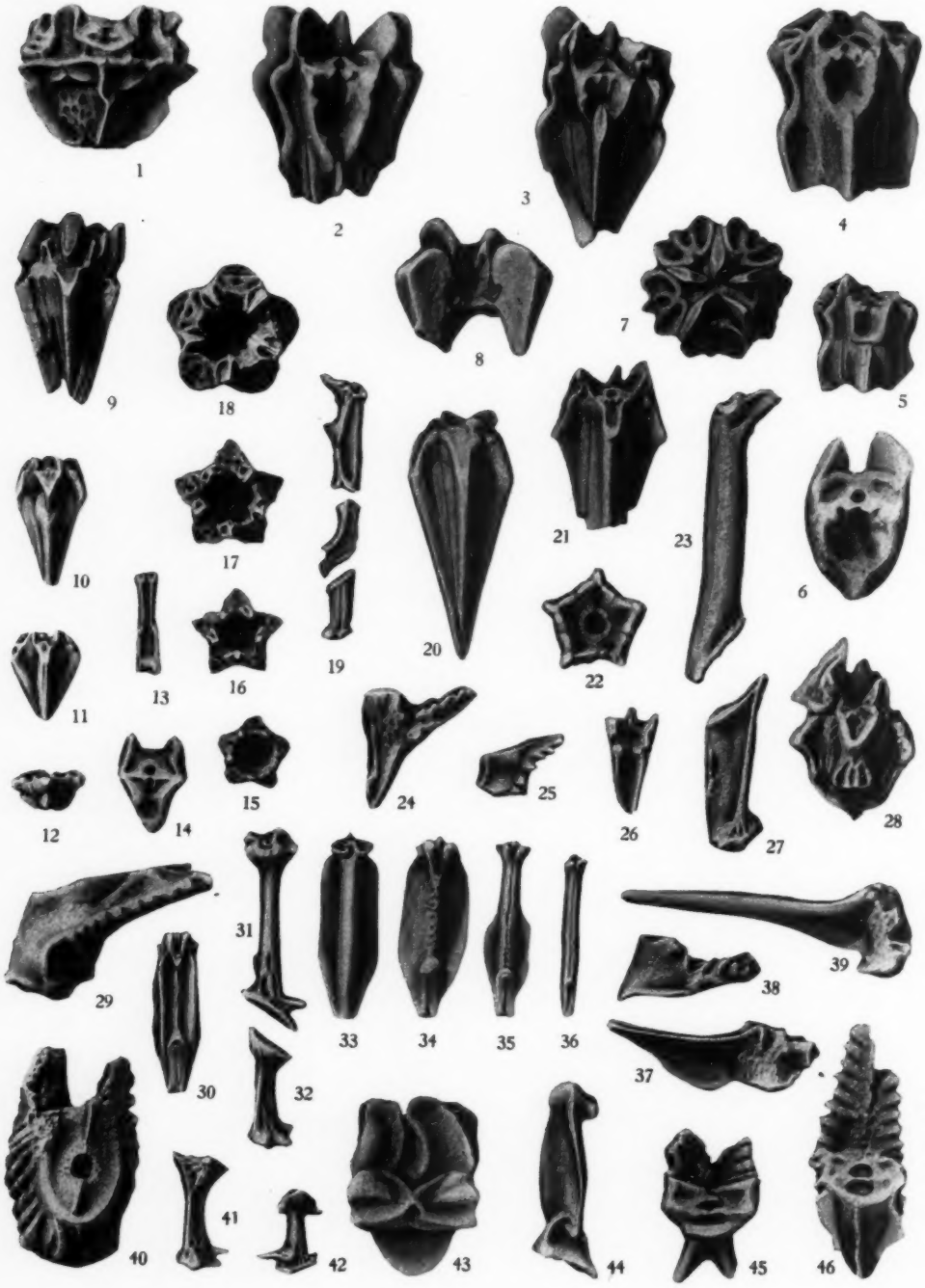
4—Poecilocrinus dispandus molestus Peck, n. var. Lateral view of holotype (E-20-5) from Main Street at overpass of Santa Fe Railroad on Belton-Temple Highway, Bell County, Texas. (p. 472)

7—Poecilocrinus dispandus elongatus Peck, n. var. Lateral view of holotype (E-21-1) Weno HTL 46, sample 253. (p. 471)

11, 14—Poecilocrinus dispandus explicatus Peck, n. var. Lateral and basal views of the holotype (E-21-2) from Main Street HTL 55, sample 279. (p. 472)



Peck, Lower Cretaceous Crinoids



Peck, Lower Cretaceous Crinoids

of the circular ridge is aboral in direction, sloping at about the same angle as the proximal portion of the arm facet. The circular ridge fails to touch the outside portion of the arm facet, but they are connected by two ridges on the outside and one in the center, creating two small depressions between the circular ridges and facet. The flanges on the aboral side may be produced into proximally pointing spines.

Types.—Holotype and figured paratypes in the University of Missouri Collections. Unfigured paratypes, Loeblich Collection no. 1020, 1021; U. S. National Museum Collection.

Occurrence.—Duck Creek and Lower Fort

EXPLANATION OF PLATE 76

All figures ×18 except *6* and *14*. All figured specimens in University of Missouri Collections. Two or more specimens with the same number are deposited in the same slide.

FIGS. *1*—*Roveacrinus latealatus* Peck, n. sp. Lateral view of paratype, Fort Worth HTL 39, sample 225. (p. 468)

2–8—*Orthogonocrinus apertus* Peck, n. sp. *2*, Lateral view of paratype (E-21-3) showing unbroken interfacet processes, Duck Creek HTL 104, sample 449. *3*, Lateral view of paratype (E-21-4) with fairly complete proximal portion, Duck Creek, HTL 76, sample 323. *4*, *6*, *7*, Lateral, detail of arm facet ×25, and summit views of holotype (E-21-5) Duck Creek HTL 57, Peck sample. *5*, Lateral view of small paratype (E-22-1), Duck Creek HTL 13, sample 122. *8*, Interior of three radials of paratype (E-22-2) showing horizontal partition, Duck Creek HTL 35, Peck sample. (p. 464)

9–22, *26*, *28*—*Drepanocrinus peracutus* Peck, n. sp. *9*, Paratype (E-22-3) with $BrBr_1$ preserved and in place, Duck Creek HTL 57, sample 291. *10*, Small paratype (E-22-4) showing a rounding in the radials just below the position of the horizontal partition, Grayson HTL 1, Peck sample. *11*, *12*, Lateral views of small paratypes (E-22-5), Duck Creek HTL 57, Peck sample. *12*, *11*, *10*, *9*, *20*, Illustrate growth stages. *13*, Interior of long brachial (E-22-5) Duck Creek HTL 57, Peck sample. *14*, Detail of arm facet on paratype ×25 (E-23-1), Fort Worth HTL 9, sample 199. *15–17*, Summit views of paratypes (E-23-2) showing (with No. 18) growth stages, Duck Creek HTL 13, sample 122. *18*, Summit of large paratype (E-22-4) Duck Creek HTL 1, Peck sample. *19*, Isolated Br_1, Br_2, and Br_3? (E-22-5) arranged in order, Duck Creek HTL 57, Peck sample. *20*, Lateral view of paratype (E-22-4) with proximal portion complete showing the pinching out of the radials proximally, Grayson HTL 1, Peck sample. *21*, Lateral view of holotype (E-23-3), Grayson HTL 1, Peck sample. *22*, Proximal view of paratype (E-23-1) with lower part broken away showing excavation in horizontal partition, Fort Worth HTL 9, sample 199. *26*, Interior of small paratype (E-22-4) showing two cavities and horizontal partition, Grayson HTL 1, Peck sample. *28*, Lateral view of paratype (E-23-4) with Br_1 preserved, Kaimichi HTL 104, sample 432. (p. 463)

23, *27*, *44*—Isolated brachials (E-23-5) of uncertain affinities, Duck Creek HTL 35, Peck sample.

24—Lateral view of nonaxial Br_2 (E-24-1) of uncertain affinities showing serrate process and truncated proximal surface HTL 57, Peck sample.

25—Lateral view of small brachial (E-24-1) with smooth distal surface for cryptosynarthial union, Duck Creek HTL 57, Peck sample.

29—Lateral view of large brachial (E-24-2) of uncertain affinities with cryptosynarthial distal surface, Duck Creek HTL 35, Peck sample.

30, *33–36*—Interior and exterior (*33*) views of isolated brachials (E-24-3) of unknown affinities. Note the surface for cryptosynarthial union at the proximal end of each brachial. The distal end is axial. Duck Creek HTL 57, Peck sample.

31, *32*, *41*, *42*—Lateral view of isolated brachials (E-24-4) of unknown affinities. *31*, Br_2 axial distally. *32*, Br_1. *41*, *42*, Beyond Br_2, Duck Creek HTL 57, Peck sample.

37, *39*—*Roveacrinus spinosus* Peck?, n. sp. *37*, Isolated brachial (E-24-5) distal to Br_2, Main Street on underpass of Highway 81 under Santa Fe Railroad north of Belton, Bell County, Texas. *39*, Isolated brachial (E-25-1) distal to Br_2, HTL 1, Peck sample. (p. 467)

38—Lateral view of isolated brachial (E-24-2) with smooth proximal surface for cryptosynarthial union, Duck Creek HTL 35, Peck sample.

40—Distal surface of isolated brachial (E-24-1) showing smooth surface for cryptosynarthial union, Duck Creek HTL 57, Peck sample.

43—Proximal surface of isolated brachial (E-25-2) distal to Br_2 showing nonserrated processes and muscular articulation surface, Grayson HTL 1, Peck sample.

45—Distal surface of isolated brachial (E-24-1) showing broken serrated processes and muscular articulation surface, Duck Creek HTL 57, Peck sample.

46—Exterior and distal portion of nonaxial Br_2 (E-24-1), Duck Creek HTL 57, Peck sample.

Worth formations. Holotype from lower Fort Worth HTL 77.

Discussion.—Immature specimens of *P. spiculatus* are difficult to distinguish from *P. porcatus* and *P. pendulus*. The distinguishing characters of *P. spiculatus* are the smallness of the bowl-shaped support, the tendency for the upper part of it to become produced into a narrow platform or two prominent spines, and the horizontal growth of the flanges on the aboral side creating a horizontal base or proximally pointing spines. *P. porcatus* does not have a horizontal base, and the bifurcation of the radial facet support takes place nearer the aboral side to produce a large V-shaped ridge below the arm facets. The upper part of this V-ridge is connected across by a subdued horizontal flange that does not extend out as far as the sides of the V-ridge on specimens of *P. pendulus*. The entire upper surface of the radial support extends proximally and laterally to produce a petalous design about the aboral portion of the calyx.

POECILOCRINUS PENDULUS Peck, n. sp.
Plate 75, figures 3, 5, 9, 10, 13

Mature calyces about 1 mm. high, with strong interfacet processes. Distal part of radial facet supports extend laterally and proximally to form a petalous platform around the proximal portion of the calyx.

Types.—Holotype and figured paratypes in the University of Missouri Collections. Unfigured paratypes, Loeblich Collection no. 1023, 1024; U. S. National Museum Collection.

Occurrence.—Duck Creek and lower Fort Worth formations. Holotype from lower Fort Worth HTL 28.

Discussion.—Immature representatives of this species are difficult to distinguish from immature *Poecilocrinus spiculatus*.

POECILOCRINUS PORCATUS Peck, n. sp.
Plate 72, figures 2–6

Calyces average about 1.6 mm. in maximum width and are wider than long in a ratio of about 4 to 3. Radial facet supports consist of flanges that divide below midheight into two strong flanges that continue distally to meet the outside proximal portion of the arm facets. Just below the arm facets weakly developed horizontal flanges or nodes connect the two vertical flanges.

Types.—Holotype and figured paratypes in the University of Missouri Collections. Unfigured paratypes, Loeblich Collection no. 1022; U. S. National Museum Collection.

Occurrence.—Duck Creek and lower Fort Worth formations. Holotype from lower Fort Worth HTL 77.

Discussion.—The distinguishing characters of this species are the shape of the calyx, the division of the radial flange low on the calyx, and the width of the vertical flanges.

Genus DISCOCRINUS[5] Peck, n. gen.

Small flattened Roveacrininae with large arm facets located on the outside of the radials and almost parallel to the dorsoventral axis. The muscular fossae are larger than in most representatives of the family and are situated on top of the radials in the sides of the interfacet processes. The proximal cavity is small, the calyx is porous, and the arms are unknown.

Genotype.—*Discocrinus catastomus* Peck, n. sp. from the Lower Cretaceous of Texas.

Discussion.—The location of the prominent arm facets on the exterior of the radials allows representatives of *Discocrinus* to be easily recognized. The well-developed centrodorsal and coarsely porous calyx establishes the relationship with the Roveacrininae.

DISCOCRINUS CATASTOMUS Peck, n. sp.
Plate 72, figures 9–11

Small, dorsoventrally flattened calyces with a maximum height of about 0.8 mm. and a maximum diameter of 1.4 mm. Proximal cavity open on most specimens because of breakage or resorption; interfacet processes weakly developed for the family and curving outward at their extremities. The proportionately large, laterally situated facets impart a pentagonal outline from the end view. Lateral view largely taken up by radial facets.

Radial facets large, pentagonal in outline, in two planes, that part proximal to the transverse ridge more nearly vertical than

[5] δίσκος—disk.

the part distal to it. Inarticular ligament fossae crescentric, curved around the large central canal, rather deeply excavated below the general surface of the facet, bounded distally by a prominent ridge. Muscular fossae comparatively large for this family, situated on the upper outside corners of the arm facet, excavated into the outside corners of the interfacet processes, opening outward and difficult to see from summit view when interfacet processes are uninjured. Situated between the muscular fossae and bounded on the outside by the crescentric ridge above the inarticular ligament fossae and bounded inside by a slight ridge is another pit. Dorsal ligament fossae large and well developed, curving around the ligament pit in a crescent.

Calyx cavity wide but shallow. Proximal cavity shallow and partially divided by interradial partitions.

Types.—Holotype and unfigured paratypes in the University of Missouri Collections. Unfigured paratypes, Loeblich Collection no. 1004; U. S. National Museum Collection.

Occurrence.—Widespread but rarely abundant in the Duck Creek and at two localities in the lower Fort Worth. One specimen in the collection is labeled Main Street, but considering the exceptionally large collection studied for this paper a single specimen from the Main Street of a genus and species otherwise limited to the Duck Creek and lower Fort Worth must be considered as possible contamination of a sample. Types from lower Fort Worth HTL 28.

Discussion.—The above description is based on 70 specimens. The outstanding characters of the species are the large arm facets on the exterior of the radials and the flattened appearance of the calyx caused by the loss of the proximal portion through breakage or resorption.

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FORAMINIFERA FROM THE DUCK CREEK FORMATION OF OKLAHOMA AND TEXAS

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ABSTRACT—One hundred and twenty species of Foraminifera are described from the Lower Cretaceous Duck Creek formation of southern Oklahoma and northern Texas, of which 37 are new. Twenty-eight of the previously described species are recorded from this formation for the first time. Five generic ranges are extended downward into the Lower Cretaceous. These are *Ammobaculoides* and *Hastigerinella*, which had not previously been recorded below the Upper Cretaceous, and *Siphotextularia*, *Unicosiphonia* and *Stichocibicides*, not previously known below the Tertiary. One new genus, *Washitella*, is described.

INTRODUCTION

THE Duck Creek is the basal formation of the Washita group of the Comanche series. The type locality of the formation is on Duck Creek, at the edge of the Red River Valley, about three miles north of Denison, Texas (locality HTL-34). The Duck Creek overlies the Kiamichi formation of the Fredericksburg group and is overlain by the Fort Worth limestone. The formation is thickest and best exposed in the northern part of the outcrop, the greatest thickness occurring in Love County, southern Oklahoma and Grayson County, northern Texas, where it is about 120 feet in thickness. The formation thins southward, being about 100 feet thick in Cooke and Denton counties and 62 feet in Tarrant County, which is the southernmost county considered in the present paper. The Duck Creek decreases in thickness still more to the south, however, being only 20 to 25 feet thick in the vicinity of Austin, in central Texas.

It is interesting to note that the most abundantly fossiliferous samples were from the north, where the formation is thickest. This is especially true of the locality in Love County, Oklahoma (HTL-13), one of the best sections for the collection of samples from the Duck Creek, although no Foraminifera have been previously recorded from this formation in Oklahoma, to the knowledge of the writer.

As the geologic range in this area is given for the various species, as far as is known, a table is given showing the formations of the Comanche series which crop out in this region, and their correlation with the European section, as evidenced by the Foraminifera.

[1] Mrs. Alfred R. Loeblich, Jr.

DESCRIPTION OF LOCALITIES AND SAMPLES

Forty-three samples were collected from eight localities, distributed through Love County in southern Oklahoma, and Grayson, Cooke, Denton and Tarrant Counties in northern Texas. These are listed below in the order of the locality numbers, as only the locality and sample numbers are given in the discussion of the various species to avoid repetition of the locality descriptions.

Locality HTL-13.—Collected in August 1939 on the west bank of the Red River, in the SW. ¼ sec. 22, T. 8 S., R. 2 E., on the southwest side of Horseshoe Bend, Love County, Oklahoma.

Sample number	Thickness (feet)	Description
122	6.5	Top of section, just beneath the basal fucoid-bearing limestone of the Fort Worth limestone. Alternating gray shales and limestones.
121	5.5	Alternating gray shale and marly limes.
120	5.5	Gray shale.
119	5.5	Gray shale.
118	5.5	Alternating gray shale and marly limestone.
117	6.5	Blue-gray shale.
116	5.5	Blue-gray shale.
115	5.5	Blue-gray shale.
114	5.5	Blue-gray shale.
113	5.5	A 6-inch limestone bed at the top, remainder alternating blue-gray shale and limestone.

SUBDIVISIONS OF THE COMANCHE SERIES

	Southern Oklahoma	Northern Texas	Southern Texas	Europe
Washita group	Grayson marl	Grayson marl	Buda limestone Del Rio clay	Albian
	Bennington ls.	Main Street ls.	Georgetown ls.	
	Bokchito fm.	Paw Paw sand Weno clay Denton clay		
	Caddo fm.	Fort Worth ls. Duck Creek fm.		
Fredericksburg group	Kiamichi clay Goodland ls.	Kiamichi clay Goodland ls. Walnut clay	Edwards ls. Comanche Peak ls. Walnut clay	
Trinity group	Trinity sand	Paluxy sand Antlers sand	Paluxy sand Glen Rose ls. Travis Peak ss.	Aptian

112	6	Upper 3 feet of blue-gray alternating shales and limestones, then a massive 2-foot limestone bed beneath this, with 1 foot of blue-gray shale beneath the limestone. Ammonites.
	5	Talus covered, no sample.
	1	Limestone ledge, no sample.
110	1	Blue-gray marl, base of section exposed.

Locality HTL-27.—Collected in July 1938 on Duck Creek, in the east bank and in the cut of the Missouri, Kansas and Texas railroad, which is above and to the east of the creek bank, east of Highway 75, 2¾ miles north of Denison, in Grayson County, Texas.

Sample number	Thickness (feet)	Description
165	1	20 feet above the base of the formation, in the cut of the Missouri, Kansas and Texas Railroad.
169	3	Light-yellow marl, alternating with marly limestone, uppermost part of section exposed in the banks of Duck Creek.
168	3	Yellow-gray marl, just below sample 169.
	1.3	Limestone, no sample.
167	2.5	Alternating blue limestones and shales.
	0.8	Marly limestone, no sample.
166	0.7	Blue-gray marl.

Sample 165 is from the railroad cut, while samples 166 to 169, inclusive, are from the creek bank and stratigraphically lower, although the exact amount below is uncertain.

Locality HTL-34.—Collected in September 1938. The type locality of the Duck Creek formation, in the banks of Duck Creek and in the railroad cut, where the St. Louis and San Francisco Railroad comes close to the creek, 2¾ miles north of Denison, on Highway 75 and east of the road, in Grayson County, Texas.

Sample number	Thickness (feet)	Description
218	10	Just below the Fort Worth limestone in the railroad cut. Yellowish-gray shale and marl with some limestones.
217	5.5	Yellowish gray shale or marl with some limestones. Just below sample 218, in the railroad cut.
	22	Grass-covered, from the base of the railroad cut to the top of the creek bank. No samples.
216	4	Light grayish-yellow marls alternating with nodular limestones.
215	5.5	Yellowish marl with a 20-inch limestone bed at the top. Fucoids on its under side.
214	5.5	Upper part of yellowish marl, becoming bluish toward the base but weathering to yellow.
213	5.5	Alternating marls and 4- to 6-inch limestones.
212	5.5	Alternating thin limestones and marls with an 11-inch limestone at the base.
211	7.2	Dark-gray shale alternating with 2- to 3-inch limestone beds.
210	5.5	Marl, with a 17-inch heavy bed of marly limestone at the base. Bottom of section, base of the Duck Creek formation.

Samples 210 to 216, inclusive, are exposed in the creek bank, samples 217 and 218 are exposed in the railroad cut above.

Locality HTL-35.—Collected in June 1939 in a road cut on the east side of the road, just inside the entrance to Forest Park, 0.4 miles due north of the northeast corner of the campus of Texas Christian University, in Fort Worth, Tarrant County, Texas. The road cut forms a 12-foot bluff.

Sample number	Thickness (feet)	Description
		Heavy limestones at top of exposure, no sample.
278	4	Interbedded nodular limestones and yellow-gray shale, just below the heavy limestones. This zone is more limy than the underlying material.
277	6	Yellow-gray shale interbedded with marly limestone toward the base. Bottom of exposure.

Locality HTL-38.—Collected in September 1938. The upper Duck Creek is exposed in a low north-facing cliff forming the south bank of Hickory Creek 150 feet north of the road, where the road leading northwest from Krum to Trinity Farms crosses the creek, 8 miles northwest of Krum, Denton County, Texas.

Sample number	Thickness (feet)	Description
224	3	Entire section exposed, alternating limestones and shaly marls, just below the stream gravel.

Locality HTL-42.—Collected in September 1938 in a high east-facing bluff on the west bank of Ammonite Creek, about 500 feet south of the road marking the northern boundary of the municipal golf course, and in about the center of the golf course, southwest of Fort Worth, Tarrant County, Texas. The bluff is about 10 feet high, and there are thin marl seams between the heavy limestone ledges, which are about 1.5 feet thick. This is only the lower part of the Duck Creek.

Sample number	Thickness (feet)	Description
240	0.2	Marl break 1 foot below the top and 9 feet above the base of the exposed section.
	3	Limestone beds, no sample.
239	0.2	Marl break 6 feet above the base.
	4	Limestone beds, no sample.
238	2	Base exposed, marly limestone.

Locality HTL-57.—Collected in June 1939 in a deep road cut on the east side of the U. S. Highway 77, just south of the bridge across the Red River, in Cooke County, Texas. This is an excellent exposure.

Sample number	Thickness (feet)	Description
296	10	Top of exposure. Marls, with a few thin limestones, grass-covered above.
295	5	Alternating thin limestones and marls, with the marls predominating.
294	5	Alternating thin limestones and marls, marls predominating.
293	5	Alternating thin limestones and thicker marls.
290	4	Thin limestone bed at the top, then 2 feet of marl with a heavy 2-foot limestone bed below.
291	6	Interbedded yellow-gray marls and limestones, just below the 2-foot limestone bed. The limestones are more abundant here than above.
292	5	Base of section exposed. Marls and limestones.

Locality HTL-60.—Collected in June 1939. The lower part of the Duck Creek formation is exposed in a low north-facing cliff on the south bank of a small stream, a short distance north of the road, 0.1 miles east of the bridge which crosses the creek, 0.9 miles east of Fink (locally called Georgetown), in Grayson County, Texas.

Sample number	Thickness (feet)	Description
300	0.7	Clay, top of section exposed.
	2.5	Limestone bed, no sample.
301	1	Clay, just below the heavy limestone bed.
302	1	Alternating thin limestones and marls.
303	1	Alternating limestones and marls, base of exposure.

The Duck Creek at this locality is composed of alternating heavy limestone beds and thin marls, with an abundance of the large ammonite *Desmoceras brazoensis*.

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Illustrations are shaded camera lucida drawings by the writer.

TYPE SPECIMENS

All figured specimens, holotypes, paratypes and hypotypes, are to be deposited in the Cushman Collection at the Cushman Laboratory for Foraminiferal Research, Sharon, Massachusetts. Paratypes and hypotypes are also to be deposited at Walker Museum, University of Chicago, and in the Loeblich Collection at Tulane University, New Orleans. However, all types are temporarily to be kept in the Loeblich Collection, pending the completion of a monographic study of the Foraminifera of the Washita group, in which the catalogue numbers of the various collections will be published.

CONCLUSIONS

A total of 120 species has been found in the Duck Creek formation, representing 59 genera and 18 families. The family Lagenidae comprises over one-third of the total number of species recovered, with the Textulariidae and Buliminidae next in number of species represented.

The geologic ranges of five genera were extended downward into the Lower Cretaceous for the first time. These are *Ammobaculoides* and *Hastigerinella*, which had not previously been recorded below the Upper Cretaceous, and *Siphotextularia*, *Unicosiphonia* and *Stichocibicides*, not previously known below the Tertiary. One new genus, *Washitella*, with two new species, is described. There are 36 other new species, making a total of 38.

Twenty-nine of the previously described 82 species were originally described from Europe, three of these being here recorded for the first time from this continent. Twenty-eight of the previously described species are first recorded from the Duck Creek formation, so that their specific ranges within the Washita group are extended.

No index species are suggested here, as the ranges in the other formations of the Washita group are as yet incompletely known. The complete geologic ranges and zonal markers for the Washita group will be discussed in a forthcoming monograph on the Foraminifera of the Washita group, by Dr. Alfred R. Loeblich and the writer.

An unusually large number of twinned specimens and freaks have been found, of both the calcareous and agglutinated types, only a few of which are illustrated. Such an occurrence in modern faunas would suggest a warm, shallow-water environment. It is hoped that more complete evidence as to the environment of the various formations of the Washita group at the time of their deposition can also be presented in the above mentioned monograph.

DESCRIPTION OF FORAMINIFERA

Family SACCAMMINIDAE

Genus LAGENAMMINA Rhumbler, 1911

LAGENAMMINA PYRIFORMIS Tappan

Plate 77, figure 1a–2b

Lagenammina pyriformis TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 94, pl. 14, figs. 1a–2b.

Reophax ampullacea Brady. CHAPMAN, *1892*, Royal Micr. Soc. Jour., p. 320, pl. 5, figs. 2a–b.

Test free, medium in size, consisting of a single globular to pyriform chamber with a narrow elongate neck and a basal spine similar in appearance to the neck; wall coarsely arenaceous, with a considerable amount of cement, cement generally chalky white, with an appearance like that of the walls of the Miliolidae and Ophthalmidiidae occurring in this horizon; aperture at the end of the elongate neck. Length of hypotype in figure 1, 0.53 mm., breadth 0.24 mm., thickness 0.19 mm.; length of hypotype in figure 2, 1.07 mm., breadth 0.31 mm., thickness 0.26 mm.

Types.—Hypotypes from locality HTL-13, sample 119.

Remarks.—This species was originally described from the Grayson formation, and the range is here extended downward to include the Duck Creek formation. The Duck Creek specimens generally are not as much compressed as were those in the Grayson, and the aperture is rounded rather than elongate. These features may be due to the preservation, however.

Family REOPHACIDAE

Genus REOPHAX Montfort, 1808

REOPHAX DECKERI Tappan

Plate 77, figure 3

Reophax deckeri TAPPAN, *1940*, Jour. Paleontol-

ogy, vol. 14, no. 2, p. 94, pl. 14, figs. 3a–b.
Reophax eckernex VIEAUX, *1941*, Jour. Paleontology, vol. 15, no. 6, p. 625, pl. 85, fig. 1.

Test free, medium-sized, elongate, flattened, periphery rounded; chambers elongate, arranged in a linear and occasionally slightly arcuate series, increasing in size quite rapidly, last chamber generally much larger than the preceding; sutures distinct, depressed; wall coarsely arenaceous, aperture at the end of a neck; color usually reddish. Length of hypotype 0.67 mm., breadth 0.22 mm., thickness 0.12 mm.

Types.—Hypotype from locality HTL-13, sample 116.

Remarks.—This species was originally described from the Grayson formation, and the range is here extended downward to include the Duck Creek formation.

REOPHAX MINUTA Tappan
Plate 77, figures 4a, b

Reophax minuta TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 94, pl. 14, figs. 4a, b.

Test free, small, flattened, periphery rounded and slightly lobulate; chambers short and broad, arranged in a linear series which is sometimes slightly arcuate, chambers increasing gradually in size as added, generally collapsed centrally or subcentrally; sutures distinct, depressed, horizontal; wall medium to finely arenaceous; aperture terminal, elongate. Length of hypotype 0.45 mm., breadth 0.15 mm., thickness 0.08 mm.

Type.—Hypotype from locality HTL-13, sample 115.

Remarks.—This species was originally described from the Grayson formation, the range being here extended downward to include the Duck Creek formation. The Duck Creek specimens are slightly less compressed than those of the Grayson, although this feature may be due to the preservation.

Genus HAPLOSTICHE Reuss, 1861
HAPLOSTICHE TEXANA (Conrad)
Plate 77, figure 5

Nodosaria texana CONRAD, *1857*, Mexican Boundary Survey, vol. 1, pt. 2, p. 159, pl. 14, fig. 4.
Haplostiche texana, PLUMMER, *1931*, Texas Univ. Bull. 3101, p. 124, pl. 15, fig. 1.
Cribrolina texana, SAMPLE, *1932*, Am. Midland Naturalist, vol. 13, p. 319.
Haplostiche texana, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 95, pl. 14, figs. 5a, b.

Test large, broad, uniserial, roughly circular in section; chambers numerous, low, in-

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EXPLANATION OF PLATE 77
Families Saccamminidae to Textulariidae

FIGS. *1, 2—Lagenammina pyriformis* Tappan. *1a, b*, ×53. *2a*, Side view, *2b*, top view, ×35. (p. 479)
3—Reophax deckeri Tappan. Side view, ×53. (p. 479)
4—Reophax minuta Tappan. *4a*, Side view, *4b*, edge view, ×53. (p. 480)
5—Haplostiche texana (Conrad). ×10. (p. 480)
6—Ammodiscus gaultinus Berthelin. Side views, ×76. (p. 481)
7—Haplophragmoides concava (Chapman). Side views, ×53. (p. 481)
8—Ammobaculites variabilis Tappan. Side view, ×35. (p. 482)
9—Ammobaculites goodlandensis Cushman and Alexander. *9a*, Side view, *9b*, edge view, ×20. (p. 481)
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19—Lituola serpula Tappan, n. sp. *19a*, Side view of holotype, *19b*, edge view, ×17. (p. 484)
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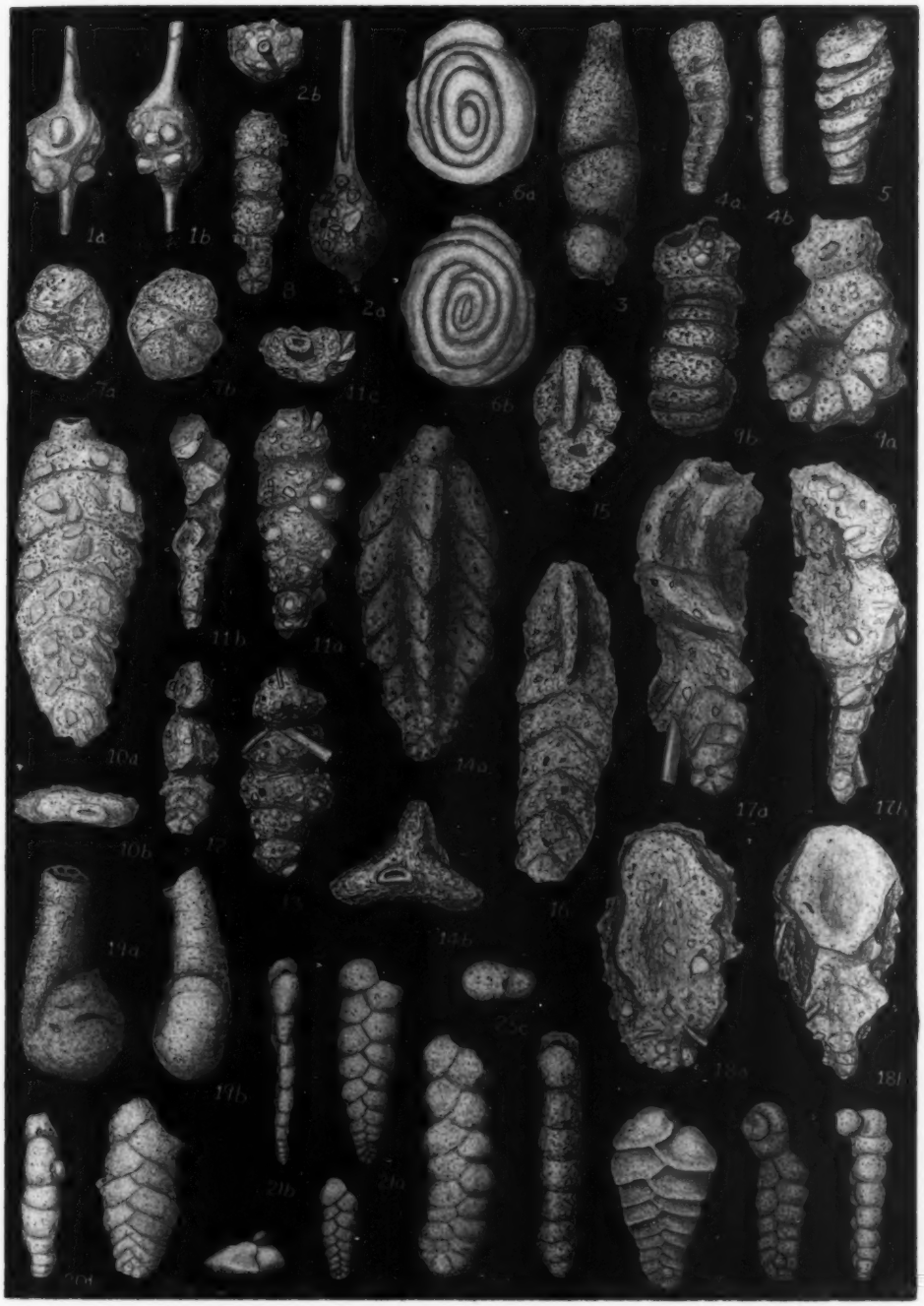
25—Ammobaculoides sp. *25a*, Side view, *25b*, edge view, ×76. (p. 485)



Tappan, Lower Cretaceous (Duck Creek) Foraminifera

creasing gradually in diameter; sutures distinct, depressed, generally straight; wall very coarsely arenaceous, very thick, labyrinthic; aperture cribrate, terminal. Length of hypotype 2.28 mm., breadth 1.29 mm.

Type.—Hypotype from locality HTL-13, sample 112.

Remarks.—*Haplostiche texana* (Conrad) has been recorded throughout the Washita group as well as from the underlying Goodland and Edwards limestones of the Fredericksburg group and the Glen Rose limestone of the Trinity group. It is best developed in the middle and upper Washita, being very abundant in some horizons of the Paw Paw formation of northern Texas and the Del Rio clay of southern Texas. It is generally rare in the Duck Creek formation and the specimens poorly preserved, crushed and twisted, as is the hypotype. The species is distinguished by its large straight test, labyrinthic wall and cribrate aperture.

Family AMMODISCIDAE
Genus AMMODISCUS Reuss, 1861
AMMODISCUS GAULTINUS Berthelin
Plate 77, figures 6a, b

Ammodiscus gaultinus BERTHELIN, *1880*, Geol. Soc. France, Mém., sér. 3, t 1, no. 5, p. 19, pl. 1 (24), figs. 3a, b.
Ammodiscus gaultinus, EGGER, *1899*, K. bayer. Akad. Wiss. München, Abh., Cl. 2, vol. 21, p. 16, pl. 1, figs. 1–3, 8–9, 30–31.
Ammodiscus gaultinus, CHAPMAN, *1917*, Geol. Survey West Australia Bull. 72, p. 18, pl. 1, fig. 8.
Ammodiscus gaultinus, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 95, pl. 14, figs. 6a–c.

Test medium-sized, discoidal, irregularly planispirally coiled, periphery rounded; proloculum slightly ovate, tubular second chamber increasing gradually in size, occasionally overlapping the preceding coil somewhat; wall very finely arenaceous, with much cement, surface irregular; aperture formed by the open end of the tubular chamber. Maximum diameter of hypotype 0.31 mm., minimum diameter 0.25 mm., thickness 0.07 mm.

Type.—Hypotype from locality HTL-13, sample 119.

Remarks.—This species has been recorded from the Grayson formation of Texas, and the range is here extended to include the Duck Creek formation. The species was originally described from France and also occurs in Germany and western Australia.

Family LITUOLIDAE
Subfamily HAPLOPHRAGMININAE
Genus HAPLOPHRAGMOIDES Cushman, 1910
HAPLOPHRAGMOIDES CONCAVA (Chapman)
Plate 77, figures 7a, b

Trochammina concava CHAPMAN, *1892*, Royal Micr. Soc. Jour., p. 327, pl. 6, figs. 14a, b.
Haplophragmoides concava, TAPPAN, *1940*, Jour Paleontology, vol. 14, no. 2, p. 95, pl. 14, figs. 7a–c.

Test small, planispiral, involute, compressed, periphery subacute; chambers increasing gradually in size, five or six usually visible; sutures fairly distinct, slightly depressed; wall finely arenaceous; aperture simple, at the base of the apertural face of the last-formed chamber. Greatest diameter of hypotype 0.29 mm., least diameter 0.24 mm., thickness 0.04 mm.

Type.—Hypotype from locality HTL-13, sample 120.

Remarks.—This species was originally described from the Gault of England and ranges throughout the Washita group of southern Oklahoma and northern Texas. Many of the specimens are flattened and distorted.

Genus AMMOBACULITES Cushman, 1910
AMMOBACULITES GOODLANDENSIS
Cushman and Alexander
Plate 77, figures 9a, b

Ammobaculites goodlandensis CUSHMAN and ALEXANDER, *1930*, Cushman Lab. Foram. Research Contr., vol. 6, p. 8, pl. 2, figs. 7, 8.
Ammobaculites goodlandensis, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 96, pl. 14, figs. 8a–9.

Test free, large, early portion coiled, last two or three chambers uncoiled, deeply umbilicate, periphery broad and truncate and angularly lobulate; chambers numerous, 10 occurring in the last volution of the coiled portion of the hypotype, chambers inflated centrally, giving the test a nodose appearance; sutures much depressed but otherwise not distinct; wall coarsely arenaceous, frequently incorporating the tests of smaller Foraminifera, such as *Globigerina;* aperture terminal. Length of hypotype 1.44 mm.,

breadth of coiled portion 0.98 mm., breadth of last chamber of uncoiled portion 0.62 mm., thickness through last chamber 0.62 mm.

Type.—Hypotype from locality HTL-13, sample 116.

Remarks.—This species was described from the Goodland formation of the Fredericksburg group and also ranges throughout the Washita.

AMMOBACULITES VARIABILIS Tappan
Plate 77, figure 8

Ammobaculites variabilis TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 97, pl. 14, figs. 12a, b.

Test free, medium-sized, elongate, early portion coiled and compressed, later uniserial and more nearly rounded in section, periphery rounded; chambers numerous, five in the coiled portion and four in the uniserial portion of the figured hypotype, increasing gradually in size throughout the coiled stage, the first uniserial chambers much larger than the preceding chambers, then the increase is again gradual in the remainder of the test, chambers inflated centrally although irregularly; sutures distinct and depressed in the early portion, and depressed but less distinct in the uniserial stage; wall finely arenaceous in the early part, coarsely arenaceous later and frequently incorporating tests of *Globigerina* and other small foraminifera; aperture terminal, elongate, at the end of a thick, short neck. Length of hypotype 0.73 mm., breadth of last chamber 0.18 mm., greatest diameter of coiled portion 0.13 mm., greatest thickness through coiled stage 0.06 mm., greatest thickness of uniserial portion 0.17 mm.

Type.—Hypotype from locality HTL-13, sample 116.

Remarks.—This species was originally described from the Grayson formation and the range is here extended to include the Duck Creek formation.

Genus FLABELLAMMINA Cushman, 1928

FLABELLAMMINA LONGIUSCULA Alexander and Smith
Plate 77, figures 10a, b

Flabellammina longiuscula ALEXANDER and SMITH, *1932*, Jour. Paleontology, vol. 6, no. 4, p. 303, pl. 45, figs. 13, 16; pl. 46, fig. 1.

Test free, large, thick, moderately compressed, early portion coiled, later uniserial, periphery rounded; chambers numerous, coiled at first, then uniserial with equitant chambers increasing very gradually in size, so that the margins of the test are nearly straight; sutures indistinct in the early part, later slightly depressed; wall coarsely arenaceous, with coarse grains embedded in a ground mass of finer material; aperture terminal, elliptical, at the end of a short, broad neck. Length of hypotype 2.60 mm., breadth 0.99 mm., thickness 0.34 mm.

Type.—Hypotype from locality HTL-13, sample 116.

Remarks.—This species was originally described from the Duck Creek formation in a road cut at the north end of Rogers Avenue, 0.38 miles north of the campus of Texas Christian University, in Fort Worth, Tarrant County, Texas, but the type locality has since been destroyed. This species ranges from the Duck Creek through the Fort Worth and Denton formations of the Washita group.

FLABELLAMMINA RUGOSA Alexander and Smith
Plate 77, figures 11a–13

Flabellammina rugosa ALEXANDER and SMITH, *1932*, Jour Paleontology, vol. 6, no. 4, p. 302, pl. 45, figs. 6–9, text fig. 1.

Test free, medium-sized, elongate, somewhat compressed, periphery rounded but irregular in outline; chambers coiled in the early portion although this cannot always be told externally, later chambers uncoiled, very slightly arched, nearly as long as broad; sutures generally indistinct, sometimes slightly depressed in the later portions of the test; wall coarsely arenaceous, with *Inoceramus* prisms and tests of *Globigerina* and other small foraminifera frequently incorporated; aperture terminal, slightly elongate. Length of topotype in figure 11, 1.38 mm., breadth 0.64 mm., greatest thickness 0.37 mm.; length of topotype in figure 12, 1.16 mm., breadth 0.38 mm.; length of topotype in figure 13, 1.53 mm., breadth 0.62 mm.

Types.—Topotypes from locality HTL-60, sample 303.

Remarks.—This species is known only from the Duck Creek formation of the Washita group, although it has also been recorded from the Upper Cretaceous Austin chalk. It

is one of the most abundant species found in the Duck Creek formation.

Genus FRANKEINA Cushman and Alexander, 1929

FRANKEINA ACUTOCARINATA Alexander and Smith

Plate 77, figures 14a, b

Frankeina acutocarinata ALEXANDER and SMITH, *1932*, Jour. Paleontology, vol. 6, no. 4, p. 307, pl. 47, figs. 1, 6.

Test free, large, elongate, flattened and planispiral in the early part, later uniserial and triangular in section, periphery angular in the early part, later becoming rounded; planispiral chambers flattened, comprising only a small portion of the test, later part uniserial, chambers increasing rapidly in size, sides deeply excavated with angles sharp at first, later rounded, chambers strongly recurved at the angles; sutures generally indistinct in the coiled part, slightly depressed in the uniserial part but sometimes indistinct except at the angles of the test; wall medium to coarsely arenaceous, generally smoothly finished; aperture elongate, at the end of a neck. Length of topotype 2.67 mm., breadth 1.14 mm.

Type.—Topotype from locality HTL-60, sample 303.

Remarks.—This is a very large species and is frequently quite abundant in the Duck Creek formation. It is limited in range to the lower Washita, having been recorded also from the Fort Worth, Denton and Weno formations.

FRANKEINA INCERTA Alexander and Smith

Plate 77, figures 15, 16

Frankeina incerta ALEXANDER and SMITH, *1932*, Jour. Paleontology, vol. 6, no. 4, p. 308, pl. 47, fig. 4.

Test free, large, early portion flattened, planispiral, later uniserial and compressed, near the apertural end becoming triangular in section, although the new angle is generally not as high as the other angles, sides only moderately excavated, periphery rounded; chambers numerous, uniserial chambers arched and increasing very gradually in size so that the sides of the test are nearly straight; sutures not distinct although occasionally slightly depressed; wall coarsely arenaceous; aperture terminal, elongate, at the end of a short, broad neck. Length of hypotype in figure 16, 2.49 mm., breadth 0.77 mm., thickness through Flabellammine stage 0.28 mm., thickness through triangular part 0.34 mm.; length of hypotype in figure 15, 1.14 mm., breadth 0.70 mm.

Types.—Hypotypes from locality HTL-13, sample 116.

Remarks.—This species was described from the Fort Worth formation, and was also recorded from the Denton. The range is here extended downward to include the Duck Creek formation. The length of the Flabellammine stage, before the addition of the third angle, is quite variable in the Duck Creek specimens, as shown in the two examples figured.

FRANKEINA INSOLITA Alexander and Smith

Plate 77, figures 17a–18b

Frankeina insolita ALEXANDER and SMITH, *1932*, Jour. Paleontology, vol. 6, no. 4, p. 308, pl. 47, figs. 2, 3.

Test free, large, early portion planispiral and compressed, then becoming abruptly thicker and quadrate in section, or somewhat irregularly flattened, sides of test in triangular or quadrate portion generally excavated, periphery in the early part fairly sharp, later rounded; chambers numerous, small in planispiral portion, increasing rapidly in size in the early part of the uniserial stage and then more gradually, so that the sides in the latter one-half of the test are nearly straight; sutures obscure, somewhat more distinct in the planispiral part than later; wall coarsely arenaceous, with *Inoceramus* prisms frequently incorporated; aperture terminal, somewhat rounded. Length of topotype in figure 18, 2.00 mm., breadth 1.20 mm., thickness 1.01 mm.; length of topotype in figure 17, 2.60 mm., greatest breadth 1.07 mm., thickness in the early portion of the test 0.28 mm., thickness near aperture 0.62 mm.

Types.—Topotype of figure 18, from sample 303, that of figure 17 from sample 301, both from locality HTL-60.

Remarks.—This is one of the most variable species of *Frankeina* in this horizon and is both large and abundant. It is known only from the Duck Creek formation.

Genus LITUOLA Lamarck, 1804
LITUOLA SERPULA Tappan, n. sp.
Plate 77, figures 19a, b

Test free, large, thick, early portion coiled, umbilicate, later uniserial, periphery broadly rounded; early chambers planispiral, about eight in the coilèd portion of the holotype, chambers quite thick, later chambers uniserial and circular in cross section, smaller in diameter than those of the coiled portion; sutures straight, indistinct and very slightly depressed; wall coarsely arenaceous, with coarse grains embedded in a ground mass of finer material, surface smoothly finished, wall labyrinthic in the interior; aperture multiple and terminal. Length of holotype 1.70 mm., breadth of coiled portion 0.86 mm., greatest thickness through coiled portion 0.62 mm., breadth at apertural end 0.41 mm.

Type.—Holotype from locality HTL-57, sample 290.

Remarks.—This species differs from *L. taylorensis* Cushman and Waters in the comparatively greater thickness of the coiled portion, the cylindrical uniserial portion, and the much less distinct sutures. *L. serpula* is also smaller, being only about one-third the size of *L. taylorensis*.

Family TEXTULARIIDAE
Subfamily SPIROPLECTAMMININAE
Genus SPIROPLECTAMMINA Cushman, 1927
SPIROPLECTAMMINA ACOSTAI
Tappan, n. sp.
Plate 77, figures 20a–c

Test small, broad and elongate, periphery rounded; chambers coiled at first, later biserial with low chambers, which then increase in height, but very slowly in breadth so that the sides of the test are nearly parallel, test also of nearly constant thickness throughout, the early part being only slightly less in thickness; sutures indistinct in the coiled portion, distinct and depressed in the biserial part; wall finely arenaceous, with considerable cement, smoothly finished; aperture an arch at the base of the last-formed chamber. Length of holotype 0.30 mm., breadth 0.15 mm., thickness 0.07 mm.

Type.—Holotype from locality HTL-34, sample 211.

Remarks.—This species differs from *S. longa* Lalicker in the broader test, more angular sutures, and greater thickness throughout. It differs from *S. nuda* Lalicker in lacking the limbate sutures and in the more nearly parallel sides and similar thickness throughout, as *S. nuda* is much more flaring, especially in the early portion. This species is named in honor of Dr. José T. Acosta, Havana, Cuba.

SPIROPLECTAMMINA AMMOVITREA Tappan
Plate 77, figures 23a–c

Spiroplectammina ammovitrea TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 97, pl. 14, figs. 13a, b.

Test tiny, elongate, slender, sides nearly parallel for most of the biserial length, test slightly broader across coiled portion than across later biserial portion, but of approximately same thickness throughout, periphery broadly rounded, very slightly lobulate; chambers numerous, five visible in coiled portion of figured hypotype, chambers of biserial portion low at first, increasing gradually in height; sutures fairly distinct, depressed in later portions; wall medium to finely arenaceous, with considerable cement, rather smoothly finished; aperture a low arch at the base of the last formed chamber. Length of hypotype 0.50 mm., breadth 0.13 mm., thickness 0.08 mm.

Type.—Hypotype from locality HTL-60, sample 303.

Remarks.—This species was originally described from the Grayson formation and the range is here extended downward to include the Duck Creek formation. The Duck Creek specimens seem to be slightly more finely arenaceous than those of the Grayson, but this may be due to environmental factors. The specimens agree closely in size and proportions. *S. ammovitrea* Tappan seems to be rare wherever found, although it ranges throughout the Washita group.

SPIROPLECTAMMINA LONGA Lalicker
Plate 77, figures 21a–22

Spiroplectammina longa LALICKER, *1935*, Cushman Lab. Foram. Research Contr., vol. 11, p. 3, pl. 1, figs. 4, 5.
Spiroplectammina longa, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 97, pl. 14, figs. 14a, b.

Test small, elongate, flattened, periphery subacute and slightly lobulate; early chambers planispiral, then biserial, with chambers at first low and then becoming higher, increasing very gradually in breadth so that the test flares very little or may even have parallel sides; sutures distinct, thickened and slightly depressed between the later chambers, slightly oblique at first, later nearly horizontal; wall finely arenaceous, smoothly finished; aperture an arch at the base of the last-formed chamber. Length of hypotype in figure 21, 0.81 mm., breadth 0.24 mm., greatest thickness 0.12 mm.; length of hypotype in figure 22, 0.40 mm., breadth 0.16 mm.

Types.—Hypotypes from locality HTL-13, sample 119.

Remarks.—This species ranges throughout the Washita group and is common in the Duck Creek formation.

SPIROPLECTAMMINA NUDA Lalicker
Plate 77, figure 24

Spiroplectammina nuda LALICKER, *1935*, Cushman Lab. Foram. Research Contr., vol. 11, p. 4, pl. 1, figs. 6, 7.
Spiroplectammina nuda, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 98, pl. 14, figs. 15a–16.

Test small, flattened, flaring gradually, thickest centrally, periphery subacute, giving a diamond-shaped cross section; chambers numerous, coiled at first, later biserial, depressed centrally; sutures limbate and raised, straight, nearly horizontal; wall finely arenaceous, with considerable cement, smoothly finished; aperture a low arch at the base of the last-formed chamber. Length of hypotype 0.33 mm., breadth 0.18 mm., thickness 0.11 mm.

Type.—Hypotype from locality HTL-13, sample 113.

Remarks.—This species was originally described from the Fort Worth and Denton formations and later recorded also from the Grayson. The range is here extended downward to include the Duck Creek formation. The specimens in the lower part of the Washita group are generally rare and smaller and less well developed than those of the upper Washita.

Genus AMMOBACULOIDES Plummer, 1932
AMMOBACULOIDES sp.
Plate 77, figures 25a, b

Test tiny, elongate, early portion coiled, later biserial with chambers increasing gradually in size and periphery subacute and lobulate, then uniserial, with test of smaller diameter and chambers nearly circular in cross-section; chambers numerous, increasing very gradually in height; sutures distinct and depressed, especially in the biserial portion; wall finely arenaceous, smoothly finished; aperture terminal, rounded. Length of specimen 0.30 mm., greatest breadth of biserial portion 0.10 mm., greatest thickness of biserial portion 0.07 mm., greatest breadth of uniserial portion 0.08 mm., greatest thickness of uniserial portion, 0.08 mm.

Type.—Locality HTL-57, sample 290.

Remarks.—The genus *Ammobaculoides* has been known only from the Upper Cretaceous and the generic range is here extended into the Lower Cretaceous. The present species differs from *A. navarroensis* Plummer in the much smaller and nearly parallel-sided test, very gradually enlarging biserial chambers, greater thickness of the test and more circular cross section of the uniserial chambers. No specific name is proposed, as the species is thus far represented by a single specimen.

Subfamily TEXTULARIINAE
Genus TEXTULARIA Defrance, 1824
TEXTULARIA RIOENSIS Carsey
Plate 78, figures 1a–4

Textularia rioensis CARSEY, *1926*, Texas Univ. Bull. 2612, p. 24, pl. 5. fig. 12.
Textularia conica d'Orbigny. CARSEY, *1926*, Texas Univ. Bull. 2612, p. 23, pl. 7, fig. 1.
Textularia rioensis, PLUMMER, *1931*, Texas Univ. Bull. 3101, p. 128, pl. 8, fig. 8.
Textularia rioensis, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 98, pl. 15, figs. 1a–2b.

Test medium-sized, flaring in outline, periphery broadly rounded; chambers numerous, biserially arranged, increasing in breadth and height fairly rapidly so that the early portion of the test is somewhat conical, later increasing more gradually; sutures distinct, depressed; wall of medium-sized grains, occasionally coarsely arenaceous and rough-textured, and at other times smoothly finished; aperture a low arch at the base of the

last-formed chamber. Length of hypotype in figure 1, 0.90 mm., breadth 0.41 mm., thickness 0.39 mm.; length of hypotype in figure 2, 0.43 mm., breadth 0.21 mm.; length of plastogamic hypotype in figure 3, 0.69 mm.; length of hypotype in figure 4, 0.49 mm., breadth 0.26 mm.

Types.—Hypotypes of figures 1, 2 and 4 from sample 120, hypotype of figure 3 from sample 116, all from locality HTL-13.

Remarks.—This is one of the most common species found in the Washita group and ranges throughout in abundance. It is also quite variable in outline, but series showing gradations between the variations can easily be selected. There are also occasional freaks and twinned specimens such as that shown in figure 3.

TEXTULARIA WASHITENSIS Carsey
Plate 78, figures 5a–9

Textularia washitensis CARSEY, *1926*, Texas Univ. Bull. 2612, p. 34, pl. 7, fig. 6.
Textularia washitensis, PLUMMER, *1931*, Texas Univ. Bull. 3101, p. 127, pl. 8, fig. 5.
Textularia washitensis, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 98, pl. 15, figs. 3–4b.

Test large, broad, elongate, biserial throughout, periphery subacute; chambers numerous, at first increasing fairly rapidly in breadth, producing a flaring test, then increasing less rapidly so that the sides of the test become subparallel, chambers also increase in height, may be either gently convex or collapsed centrally; sutures distinct, depressed, usually giving a somewhat lobulate periphery, but in some specimens when the chambers are collapsed the sutures are left slightly elevated; wall of medium-sized grains, usually smoothly finished; aperture a low arch at the base of the last-formed chamber. Length of hypotype of figure 5, 1.21 mm., breadth 0.54 mm., thickness 0.29 mm.; length of hypotype of figure 6, 1.12 mm., breadth 0.43 mm.; length of hypotype of figure 7, 1.19 mm., breadth 0.42 mm.; length of hypotype of figure 8, 0.81 mm., breadth 0.48 mm., thickness 0.26 mm.

Types.—Hypotypes of figures 5 and 8 from locality HTL-57, sample 296; hypotypes of figures 6 and 9 from locality HTL-13, sample 114; hypotype of figure 7 from locality HTL-38, sample 224.

Remarks.—This species occurs abundantly throughout the Washita group. However, specimens from the lower Washita, as in the Duck Creek, are perhaps better developed than later forms, as the specimens are unusually long and broad. Also the tests generally show less collapse of the chambers and have depressed sutures, a more flaring test, and a more angular periphery. Those in the upper Washita show definitely collapsed chambers and the resultant higher sutures, and a more parallel-sided test and blunt periphery. Some gradation may be observed in all of the formations, as is shown by the specimens figured.

TEXTULARIA DUCKCREEKENSIS
Tappan, n. sp.
Plate 78, figures 10a–c

Test of medium size, considerably flattened, periphery subacute; chambers numerous, biserially arranged, increasing gradually in height and breadth so that the test flares slightly, chambers may be very faintly depressed centrally; sutures distinct, raised and limbate; wall arenaceous, composed of medium-sized grains, surface rough; aperture slightly elongate, apparently in the face of the last-formed chamber, rather than at its base. Length of holotype 0.70 mm., breadth 0.35 mm., thickness 0.10 mm.

Type.—Holotype from locality HTL-27, sample 169.

Remarks.—This species is somewhat similar in appearance to *T. washitensis* Carsey but differs in the much more compressed test and less tapering of the initial portion, comparatively higher chambers, rougher appearance, and in the character of the aperture.

Genus SIPHOTEXTULARIA Finlay, 1939

SIPHOTEXTULARIA SUBCRETACEA
Tappan, n. sp.
Plate 78, figures 11a–c

Test medium-sized, elongate, quadrate in section, biserial throughout, sides excavated, periphery sharply keeled; chambers increase very gradually in size so that the sides of the test are subparallel, sutures slightly thickened but flush with the surface and indistinct; wall medium to coarsely arenaceous, with considerable cement; aperture in the

face of the last formed chamber, surrounded by a lip. Length of holotype 0.66 mm., breadth 0.26 mm., greatest thickness 0.22 mm., thickness through last chamber 0.17 mm.

Types.—Holotype from locality HTL-27, sample 169.

Remarks.—The genus *Siphotextularia* Finlay has been known previously only from the Tertiary and Recent. The generic range is here extended downward into the Lower Cretaceous. The present species is apparently a very primitive member of the genus but agrees in the quadrangular section and the character of the aperture. The typical *Siphotextularia* has the aperture at the end of a short tubular extension in the apertural face, somewhat above the basal margin. The aperture of *S. subcretacea* is in the same position, but instead of a definite tubular neck has only a raised, liplike area surrounding the aperture.

Siphotextularia subcretacea differs from *S. wairoana* Finlay in having a slightly larger test, keeled margins, a longer aperture with a surrounding lip rather than a tubular process, and in possessing less distinct sutures.

Genus BIGENERINA d'Orbigny, 1826
BIGENERINA WINTONI Cushman and Alexander
Plate 78, figures 12–16

Bigenerina wintoni CUSHMAN and ALEXANDER, *1930*, Cushman Lab. Foram. Research Contr., vol. 6, p. 9, pl. 2, figs. 15a, b.

Bigenerina wintoni, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 99, pl. 15, figs. 5a, b.

Test large, elongate, flattened, early portion biserial, periphery sharply truncate, later uniserial and periphery rounded; biserial chambers slightly collapsed centrally and increase gradually in size so that the sides of the test are subparallel, uniserial chambers much larger and rounded in section; sutures generally distinct, oblique, thickened and raised in the biserial portion, straight and depressed in the uniserial portion, the amount of depression varying, so that the uniserial portion may be cylindrical, or constricted at the sutures and beadlike; wall arenaceous, composed of medium-sized grains, surface rough; aperture terminal, rounded. Length of hypotype in figure 12, 1.91 mm., greatest breadth of biserial portion 0.30 mm., breadth of uniserial portion 0.41 mm.; length of topotype in figure 13, 0.53 mm.; length of hypotype in figure 14, 0.27 mm., breadth 0.19 mm., thickness 0.08 mm.; length of topotype in figure 15, 0.69 mm., breadth 0.17 mm.; length of topotype in figure 16, 1.20 mm., breadth of biserial portion 0.24 mm., thickness of biserial portion 0.16 mm., breadth of uniserial portion 0.19 mm., thickness of uniserial portion 0.20 mm.

Types.—Hypotype of figure 12 from sample 118, hypotype of figure 114 from sample 121, both from locality HTL-13; topotypes of figures 13, 15 and 16 all from locality HTL-27, sample 169.

Remarks.—*Bigenerina wintoni* Cushman and Alexander ranges throughout the Washita group but is rare in the upper formations, while it is abundant in the Duck Creek formation. There is considerable variation in the length of the biserial and uniserial stages, as well as in the character of the uniserial portion. These variations are shown in the figured specimens and may represent the microspheric and megalospheric generations. The specimens in the upper Washita show poor development of the uniserial stage, and the uniserial chambers are collapsed centrally in some specimens, rather than cylindrical or beadlike.

Family VERNEUILINIDAE
Genus TRITAXIA Reuss, 1860
TRITAXIA PLUMMERAE Cushman
Plate 78, figures 17–21

Tritaxia plummerae CUSHMAN, *1936*, Cushman Lab. Foram. Research Spec. Pub. 6, p. 3, pl. 1, figs. 7a, b; *1937*, idem, Spec. Pub. 7, p. 24, pl. 3, figs. 12–15.

Tritaxia pyramidata Reuss. PLUMMER, *1931*, Texas Univ. Bull. 3101, p. 133, pl. 10, figs. 18, 19, 21 (not fig. 20).

Test, large, thick, triangular, triserial at first with flat or very slightly concave sides and sharp angles, later with one or two uniserial chambers, which are rounded in section; chambers increase fairly rapidly in the early part of the test until the approximate adult dimensions are reached, then increase more slowly so that the sides are nearly straight for most of the length of the test, uniserial chambers much larger in size and subglobular; sutures oblique, generally indistinct, occasionally slightly depressed; wall finely arenaceous, smoothly finished;

aperture a low arch at the base of the last-formed chamber during the triserial development, then becoming terminal and rounded in the uniserial chambers. Length of megalospheric topotype in figure 19, 0.78 mm., breadth 0.53 mm.; length of microspheric topotype in figure 18, 1.38 mm., breadth 0.53 mm.; length of topotype in figure 21, 1.34 mm., breadth 0.43 mm.; length of twinned specimen in figure 20, 1.10 mm.; length of megalospheric hypotype in figure 17, 0.94 mm., breadth 0.62 mm.

Types.—Topotypes of figures 18, 19 and 21 from locality HTL-42, sample 240; hypotypes of figure 20 from sample 113, and of figure 17 from sample 121, both from locality HTL-13.

Remarks.—This species is known only from the Duck Creek and Fort Worth formations of the lower Washita and is quite abundant in the samples where it occurs. There is some variation in the degree of development of the uniserial stage, possibly those with widely flaring triserial tests and poor uniserial development being the megalospheric individuals, while the microspheric form generally possesses a less flaring triserial portion and two or three uniserial chambers.

Plummer, in referring this species to *Tritaxia pyramidata* Reuss, illustrated four specimens, one of which showed a well-developed biserial stage, but no uniserial chambers. According to Plummer (1931, p. 134),

> A rare development in tests of this species in the Duck Creek formation is the loss of one row of chambers, thus giving rise to a dimorphous form that changes from triserial to biserial.

Although the types have not been examined by the present writer, it is very probable that the biserial specimens are *Gaudryina alexanderi* Cushman rather than *Tritaxia plummerae* Cushman, as the two species occur together and are of similar size. *T. plummerae* differs in the absence of the biserial stage and in the more rounded angles of the test. The sutures are slightly depressed, while they are thickened in *G. alexanderi* and not depressed. Furthermore, the wall of *T. plummerae* is more finely arenaceous and more smoothly finished.

Genus GAUDRYINA d'Orbigny, 1839
GAUDRYINA ALEXANDERI Cushman
Plate 78, figures 22–27

Gaudryina alexanderi CUSHMAN, *1936*, Cushman Lab. Foram. Research Spec. Pub. 6, p. 6, pl. 1, figs. 13a, b; *1937*, idem, Spec. Pub. 7, p. 35, pl. 4, fig. 13.
Tritaxia pyramidata Reuss (part). PLUMMER *1931*, Texas Univ. Bull. 3101, p. 133, pl. 10, fig. 20.

Test large, triangular and triserial at the base, periphery of triserial portion sharply

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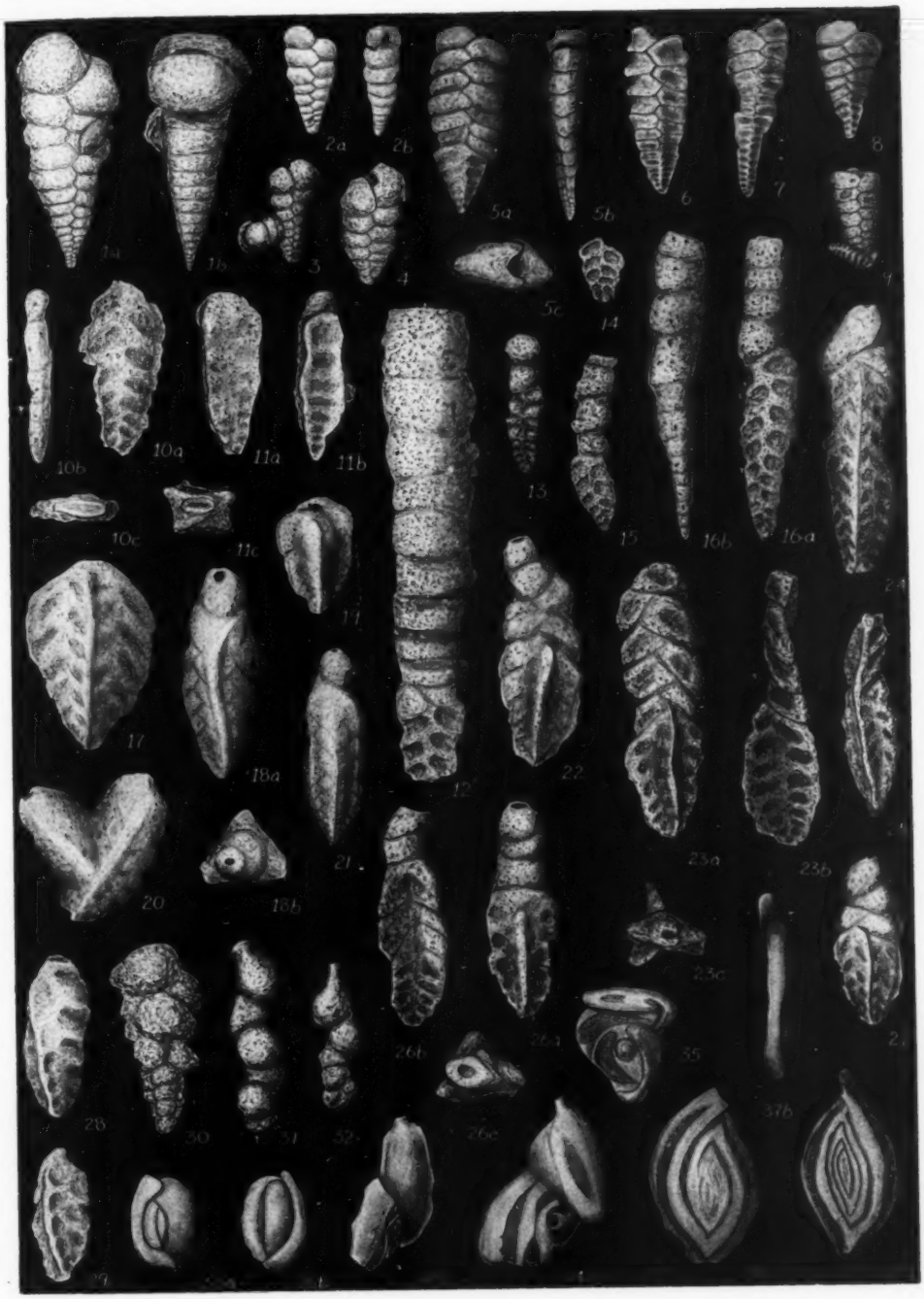
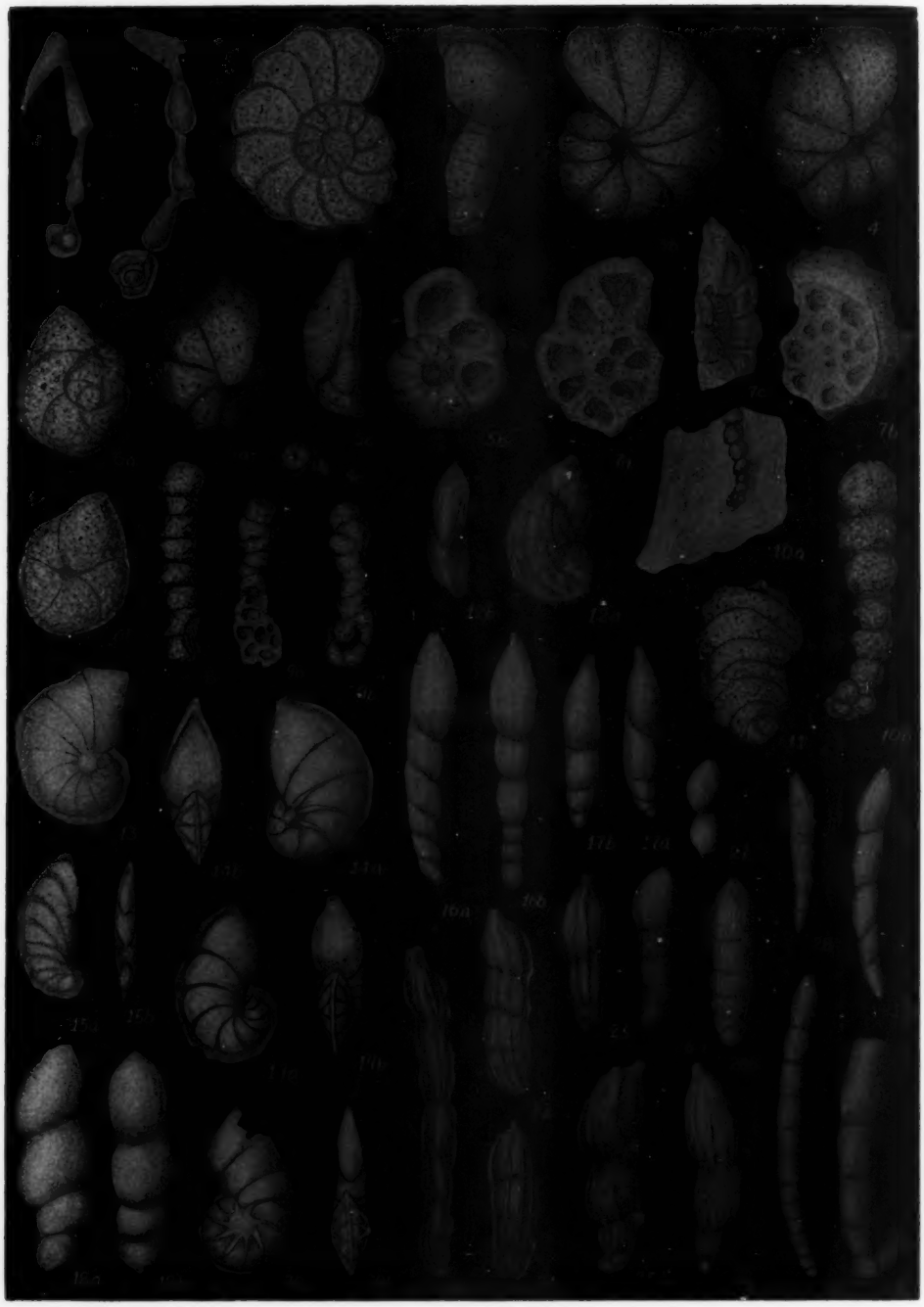
EXPLANATION OF PLATE 78
Families Textulariidae to Ophthalmidiidae

FIGS. *1–4—Textularia rioensis* Carsey. *1a, 2a, 4*, Side views, *1b, 2b*, edge views, ×35. *3*, Plastogamic individual, ×20. (p. 485)
5–9—Textularia washitensis Carsey. *5a, 6–9*, Side views, *5b*, edge view, ×20. *5c*, top view, ×27. *9*, Plastogamic individual. (p. 486)
10—Textularia duckcreekensis Tappan, n. sp. *10a*, Side view of holotype, *10b*, edge view, *10c*, top view, ×35. (p. 486)
11—Siphotextularia subcretacea Tappan, n. sp. *11a*, Side view of holotype, *11b*, edge view, *11c* top view, ×35. (p. 486)
12–16—Bigenerina wintoni Cushman and Alexander. *12, 14*, Hypotypes, *13, 15, 16*, topotypes *12–16a*, Side views, *16b*, edge view, ×35. (p. 487)
17–21—Tritaxia plummerae Cushman. *17*, Side view of hypotype, ×27. *18a, 19, 21*, Side views of topotypes, *18b*, top view, *20*, side view of plastogamic hypotype, ×20. (p. 487)
22–27—Gaudryina alexanderi Cushman. *22, 23, 25, 26*, Hypotypes, *24, 27*, topotypes. *23c* and *26c*, Top views, other views from the side, *22, 26, 27* show uniserial development, ×27. (p. 488)
28, 29—Gaudryina subcretacea Cushman. Side views of topotypes, ×27. (p. 490)
30—Gaudryinella delrioensis Plummer. Side view, ×76. (p. 490)
31, 32—Gaudryinella irregularis Tappan, n. sp. *31*, Side view of holotype. *32*, Side view of paratype, ×76. (p. 490)
33—Quinqueloculina minima Tappan, n. sp. Side views of holotype, ×76. (p. 490)
34, 35—Ophthalmidium adhaerens Tappan, n. sp. *34a*, Side view of holotype, *34b*, edge view, ×57, *35*, side view of paratype, ×76. (p. 491)
36, 37—Ophthalmidium minima Tappan, n. sp. *36*, Side view of paratype, *37a*, side view of holotype, *37b*, edge view, ×57. (p. 491)



Tappan, Lower Cretaceous (Duck Creek) Foraminifera



Tappan, Lower Cretaceous (Duck Creek) Foraminifera

angular and sides excavated, later biserial and flattened, biserial portion convex on the side where the third angle formerly appeared, concave on the opposite side, periphery subacute, in a few specimens there may also be one or more terminal, rounded uniserial chambers; chambers increase rapidly in size at first, so that the base of the triserial portion flares widely, then the increase is gradual throughout the remainder of the test, breadth is decreased where the third series of chambers is lost and the biserial stage begins, and also where uniserial development begins in the few specimens possessing such development; sutures generally indistinct in triserial portion of test, but depressed and distinct in the biserial and uniserial stages; wall arenaceous, composed of medium-sized grains, with considerable cement and smoothly finished; aperture an arch at the base of the last-formed chamber in typical development, but when uniserial chambers appear the aperture becomes terminal and rounded. Length of hypotype in figure 22, 1.18 mm., breadth of triserial portion 0.43 mm., breadth of biserial portion 0.41 mm., thickness of biserial portion 0.17 mm., breadth of uniserial chambers 0.20 mm.; length of hypotype in figure 23, 1.42 mm., breadth of triserial portion 0.41 mm., breadth of biserial portion 0.43 mm., thickness of biserial portion 0.175 mm.; length of topotype in figure 24, 1.38 mm., breadth 0.40 mm.; length of hypotype in figure 25, 1.02 mm., breadth 0.29 mm.; length of hypotype in figure 26, 1.13 mm.; breadth of triserial portion 0.36 mm., breadth of uniserial portion 0.18 mm.; length of topotype in figure 27, 0.86 mm., breadth 0.36 mm.

Types.—Hypotypes of figures 22 and 25 from sample 115, hypotypes of figures 23 and 26 from sample 114, all from locality HTL-13; topotypes of figures 24 and 27 from locality HTL-42, sample 240.

Remarks.—This species is known only from the Duck Creek formation and is quite common in the samples where it occurs.

According to Cushman, the aperture in typical specimens tends to become somewhat terminal, suggesting a tendency toward *Gaudryinella*. However, he stated that no definite uniserial stage was found in his material. Although uniserial forms have now been found, they are not common, and the species is left with the genus *Gaudryina*, as that seems to be the typical development,

EXPLANATION OF PLATE 79

Families Ophthalmidiidae to Lagenidae

FIGS. *1, 2—Nubecularia depressa* Chapman. Side views, ×53. (p. 491)

3–5—Trochammina krumensis Tappan, n. sp. *3*, Holotype, *4, 5*, paratypes. *3a, 5b*, Dorsal views, *3b, 4, 5a*, ventral views, *3c, 5c*, edge views, ×76. (p. 492)

6—Trochammina obliqua Tappan, n. sp. *6a*, Dorsal view of holotype, *6b*, ventral view, ×53. (p. 492)

7—Trochammina truncata Tappan, n. sp. *7a*, Ventral view of holotype, *7b*, dorsal view, *7c*, edge view, ×53. (p. 492)

8, 9—Placopsilina longa Tappan. *8*, Lateral view, ×17. *9a*, Attached surface, *9b*, external side view, *9c*, top view, ×10. (p. 493)

10—Placopsilina minima Tappan, n. sp. *10a*, Side view of holotype, showing attachment, ×20. *10b*, Side view, enlarged, ×53. (p. 493)

11—Placopsilina expansa Tappan, n. sp. Side view of holotype, ×35. (p. 493)

12—Darbyella subcretacea Tappan, n. sp. *12a*, Dorsal view of holotype, *12b*, edge view, ×35. (p. 493)

13–15—Lenticulina gaultina (Berthelin). *13*, Side view, ×20. *14a*, Side view, *14b*, face view, ×53. *15a*, Side view, *15b*, face view, ×17. (p. 494)

16, 17—Marginulina paucicosta Tappan, n. sp. *16*, Holotype, *17*, paratype, *16a, 17a*, side views, *16b, 17b*, edge views, ×53. (p. 494)

18—Marginulina planitesta Tappan, n. sp. *18a*, Side view of holotype, *18b*, edge view, ×76. (p. 495)

19, 20—Marginulina lenticulinoidea Tappan, n. sp. *19*, Holotype, *20*, paratype, *19a, 20a*, side views, *19b, 20b*, face views, ×35. (p. 494)

21–25—Marginulina tenuissima Reuss. *21–25a*, Side views, *25b*, face view, ×35. (p. 495)

26—Marginulina striatifera Tappan, n. sp. *26a*, Side view of holotype, *26b*, edge view, ×35. (p. 495)

27—Dentalina sp. Side view, ×46. (p. 496)

28, 29—Dentalina communis (d'Orbigny). Side views, ×35. (p. 495)

30, 31—Dentalina cylindroides Reuss. *30*, side view, ×17, *31*, abnormal specimen, ×53. (p. 495)

while the few *Gaudryinella*-like specimens show a tendency, but are not considered diagnostic.

GAUDRYINA SUBCRETACEA Cushman
Plate 78, figures 28, 29

Gaudryina subcretacea CUSHMAN, *1936*, Cushman Lab. Foram. Research Spec. Pub. 6, p. 5, pl. 1, figs. 11a, b; *1937*, idem, Spec. Pub. 7, p. 35, pl. 4, figs. 12a, b.

Test, medium-sized, triserial and flattened-triangular at the base, later biserial, periphery subacute; chambers increasing gradually in size, generally slightly collapsed centrally; sutures fairly distinct, thickened and raised; wall rather coarsely arenaceous, may be smoothly finished or somewhat rough; aperture at the base of the last-formed chamber, extending upward into the apertural face. Length of topotype in figure 28, 0.84 mm., breadth 0.34 mm., thickness 0.23 mm.; length of topotype in figure 29, 0.70 mm., breadth 0.30 mm.

Types.—Topotypes from locality HTL-34, sample 212.

Remarks.—This species is known only from the Duck Creek formation, and occurs rarely. It is distinguished from *G. alexanderi* Cushman by its smaller size and flattened triserial portion. One of the sides of *G. subcretacea* has much less breadth than the others, so that the third angle, which is eventually lost, is somewhat to one side of the center of the test.

Genus GAUDRYINELLA Plummer, 1931
GAUDRYINELLA DELRIOENSIS Plummer
Plate 78, figure 30

Gaudryinella delrioensis PLUMMER, *1931*, Am. Midland Naturalist, vol. 12, p. 341, text figs. 1a, b; *1931*, Texas Univ. Bull. 3101, p. 137, pl. 9, fig. 13.
Gaudryinella delrioensis, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 99, pl. 15, fig. 7. Includes additional synonymy.

Test small, elongate, early chambers triserially arranged, later closely biserial, grading into loosely arranged biserial chambers and then becoming rectilinear and finally uniserial; chambers increase rapidly in size, low at first and then rapidly becoming higher, inflated centrally; sutures distinct and much depressed; wall coarsely arenaceous, roughly finished; aperture at the base of the last-formed chamber during triserial and biserial development, then becoming terminal in the uniserial chambers. Length of hypotype 0.35 mm., breadth 0.17 mm.

Types.—Hypotype from locality HTL-13, sample 118.

Remarks.—*Gaudryinella delrioensis* Plummer ranges throughout the Washita group but is rare in the lower part, being best developed in the Del Rio clay of southern Texas. The Duck Creek specimens are generally small, none with a truly uniserial development having been observed.

GAUDRYINELLA IRREGULARIS
Tappan, n. sp.
Plate 78, figures 31–32

Test tiny, elongate, very early portion triserial, forming a somewhat globular base, then rapidly becoming loosely triserial and finally uniserial; chambers inflated, globular, later ones becoming somewhat elongate, increasing rapidly in size from the initial portion, then increasing more slowly; sutures distinct, deeply depressed; wall medium to finely arenaceous, smoothly finished; aperture terminal, rounded, at the end of a distinct neck. Length of holotype 0.34 mm., breadth of last chamber 0.08 mm., length of paratype 0.27 mm., breadth of last chamber 0.08 mm.

Types.—Holotype and paratype from locality HTL-27, sample 169.

Remarks.—This species occurs more abundantly in the Duck Creek formation than does *G. delrioensis* Plummer, from which it differs in its smaller size and more delicate test, much less well developed triserial and biserial stages, more elongate and loosely arranged uniserial chambers, smoothly finished wall and the elongate neck. *G. irregularis* shows a tendency toward the characters of *Pseudoclavulina*, as the biserial stage is poorly developed and the aperture occurs at the end of a distinct neck. This bears out the suggested derivation of the latter genus from *Gaudryinella*.

Family MILIOLIDAE
Genus QUINQUELOCULINA d'Orbigny, 1826
QUINQUELOCULINA MINIMA Tappan, n. sp.
Plate 78, figures 33a, b

Test very tiny, ovate, periphery bluntly

rounded; chambers added in typical quinqueloculine fashion, last chambers overlapping a large proportion of the earlier ones on the side where four chambers are visible, where only three are visible the central chamber occupies over one-third of the breadth, chambers quite thick; sutures distinct, depressed; wall calcareous, imperforate; aperture simple, at the end of the chamber, no tooth visible. Length of holotype 0.182 mm., breadth 0.12 mm., thickness 0.10 mm.

Type.—Holotype from locality HTL-57, sample 296.

Remarks.—This species differs from *Quinqueloculina seminula* (Linné) in its much smaller size, bluntly rounded periphery, and in lacking the apertural tooth.

Family OPHTHALMIDIIDAE
Subfamily OPHTHALMIDIINAE
Genus OPHTHALMIDIUM Zwingli and Kübler, 1870
OPHTHALMIDIUM ADHAERENS
Tappan, n. sp.
Plate 78, figures 34a–35

Test small, flattened, apparently attached, planispiral, with globular proloculum followed by chambers of one-half coil in length, later chambers decreasing in length so that there are three to a coil in the adult; chambers increasing rapidly in size and last chambers much inflated, with a triangular cross section; sutures indistinct, but centers of chambers usually of clear or darker calcite so that the chambers can be distinguished; wall calcareous, imperforate, mostly of a chalky white color; aperture at the end of the chamber and may be on a slight neck. Greatest diameter of holotype 0.41 mm., breadth 0.37 mm., thickness 0.15 mm.; greatest diameter of paratype 0.17 mm., breadth 0.20 mm., thickness 0.06 mm.

Types.—Holotype from sample 116, paratype from sample 119, both from locality HTL-13.

Remarks.—Both specimens figured seem to show a reverse in the direction of coiling in the development of the test, a feature noticed in other species of this genus by Macfadyen (1939), who stated,

> In one figure of *O. ovale* Burbach and in two of my specimens of *O. acutimargo* the direction of coiling is reversed at one point in the development from a clockwise to a counter-clockwise direction.

O. adhaerens differs from *O. inconstans* Brady in the much smaller size and in possessing definitely three-chambered whorls, which are in contact, without an intervening plate. The specimens are very much flattened on one side and seem to have been attached, although this is not characteristic of the genus.

OPHTHALMIDIUM MINIMA
Tappan, n. sp.
Plate 78, figures 36–37b

Test small, flattened, periphery bluntly rounded; ovate proloculum followed first by a tubular chamber and then by two chambers to a coil; chambers clear in the center so that their arrangement can be seen, but sutures themselves are indistinct; wall calcareous, imperforate; aperture simple, at the end of the chamber. Length of holotype 0.46 mm., breadth 0.23 mm., thickness 0.05 mm.; length of paratype 0.44 mm., breadth 0.26 mm., thickness 0.05 mm.

Types.—Holotype from locality HTL-13, sample 114; paratype from locality HTL-35, sample 277.

Remarks.—This species differs from *O. acutimargo* (Brady) in the much smaller size and more numerous and narrower chambers, blunt periphery and comparatively less flattening. This species is of the type designated *Spirophthalmidium* by Cushman, but according to Macfadyen the genotypes of *Ophthalmidium* and *Spirophthalmidium* are congeneric. Hence, the present species is described under *Ophthalmidium*.

Subfamily NUBECULARIINAE
Genus NUBECULARIA Defrance, 1825
NUBECULARIA DEPRESSA Chapman
Plate 79, figures 1, 2

Nubecularia depressa CHAPMAN, *1891*, Royal Micr. Soc. Jour., p. 572, pl. 1 (9), fig. 1.

Test tiny, slender, attached; globular proloculum followed by a single coil consisting of two chambers, early chambers not in contact but joined by a thin plate, then chambers become uniserially arranged in a straight or arcuate series, chambers pyriform in outline, blunt and rounded proximally, tapering toward the aperture; su-

tures indistinct in the early portion, distinct in the uniserial part; wall calcareous, imperforate; aperture simple, terminal. Length of hypotype in figure 1, 0.59 mm., length of a single uniserial chamber 0.19 mm., breadth of coil 0.10 mm.; length of hypotype of figure 2, 0.69 mm., greatest breadth of coil 0.13 mm., least breadth of coil 0.126 mm., greatest breadth of uniserial chamber 0.056 mm.

Types.—Hypotypes from locality HTL-13, sample 120.

Remarks.—This species was originally described from the Gault of England, and the geographic range is here extended to the Duck Creek formation of Texas and Oklahoma.

Family TROCHAMMINIDAE
Genus TROCHAMMINA Parker and Jones, 1859
TROCHAMMINA KRUMENSIS
Tappan, n. sp.
Plate 79, figures 3a–5c

Test small, attached dorsally; ventrally slightly umbilicate, dorsal side flattened, ventral side convex, periphery rounded, lobulate; chambers numerous, 9 to 12 visible on the ventral side, the variation perhaps due to the difference in microspheric and megalospheric generations, about two or three whorls visible dorsally, chambers increasing very gradually in size, last chamber generally quite inflated, and in a few specimens extends somewhat ventrally over the umbilicus, wall of some chambers absent on the dorsal side by which the test was attached, so that the chambers open onto the attachment; sutures distinctly depressed ventrally, observable also on the dorsal side; wall thick, finely arenaceous, generally reddish in color; aperture at the inner margin of the ventral side of the chamber. Greatest diameter of holotype 0.38 mm., least diameter 0.29 mm., greatest thickness 0.15 mm.; greatest diameter of paratype in figure 4, 0.36 mm., least diameter 0.23 mm., thickness 0.13 mm.; greatest diameter of paratype in figure 5, 0.29 mm., least diameter 0.21 mm., thickness 0.10 mm.

Types.—Holotype from locality HTL-38, sample 224; paratype of figure 4 from locality HTL-57, sample 295; paratype of figure 5 from locality HTL-27, sample 165.

Remarks.—This species is probably the most common species of *Trochammina* in the Duck Creek formation. It is distinguished from *T. inflata* (Montagu) in the more inflated last chamber, greater number of chambers, sharper periphery and ventral attachment. It is distinguished from *T. obliqua* Tappan by the inflated chambers, less oblique sutures, ventral attachment and lobulate periphery.

TROCHAMMINA OBLIQUA
Tappan, n. sp.
Plate 79, figures 6a, b

Test free, tiny, trochoid, flattened, ventrally umbilicate, convex dorsally, periphery subacute; chambers numerous, five in the last whorl, increasing rapidly in size; sutures distinct, depressed, oblique on the dorsal side but only slightly curved ventrally; wall finely arenaceous, with considerable cement; aperture an arch at the base of the apertural face of the last-formed chamber. Greatest diameter of holotype 0.37 mm., least diameter 0.28 mm., thickness 0.08 mm.

Type.—Holotype from locality HTL—13, sample 120.

Remarks.—This species differs from *Trochammina diagonis* Carsey in the less lobulate periphery, more oblique sutures dorsally, and smaller size.

TROCHAMMINA TRUNCATA
Tappan, n. sp.
Plate 79, figures 7a–c

Test small, trochoid, attached ventrally, ventral side flattened, dorsal side flattened and concave centrally, periphery broadly truncate; chambers numerous, seven in the last volution, about 2½ whorls visible dorsally, chambers increasing gradually in height, increasing rapidly in thickness, collapsed dorsally; sutures straight, thickened, distinct; wall thick, finely arenaceous, with considerable cement; aperture apparently at the base of the apertural face of the last chamber, slightly toward the dorsal side. Greatest diameter of holotype 0.43 mm., least diameter 0.40 mm., thickness 0.15 mm.

Type.—Holotype from locality HTL-35, sample 278.

Remarks.—This species differs from *T. krumensis* in the flattened dorsal side and

bluntly truncate periphery, and the straight, nondepressed sutures.

Family PLACOPSILINIDAE
Genus PLACOPSILINA d'Orbigny, 1850
PLACOPSILINA LONGA Tappan
Plate 79, figures 8–9c

Placopsilina longa TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 100, pl. 15, figs. 9a–10.

Test large, early portion coiled, attached, later uniserial and usually growing free of the attachment, periphery sharp in the attached portion, later free uniserial chambers rounded in section; usually five chambers present in the coil, with a very large umbilical plug protruding above the remainder of the chambers, but occasionally broken out, uniserial chambers short, increasing very slowly in diameter, frequently the uniserial portion is broken from the attached portion of the test and occurs as a straight series of chambers; sutures distinct, straight, depressed; wall thick, coarsely arenaceous; aperture terminal on the rounded uniserial chambers. Length of hypotype in figure 8, 1.61 mm., thickness 0.30 mm.; length of hypotype in figure 9, 2.26 mm., breadth of coiled portion 0.73 mm., thickness through coil 0.37 mm., breadth of uniserial portion 0.52 mm.

Types.—Hypotype of figure 8 from locality HTL-13, sample 113; hypotype of figure 9 from locality HTL-60, sample 303.

Remarks.—This species was originally described from the Grayson formation, has been recorded in a faunal list from the Denton formation, and the range is here extended downward to include the Duck Creek formation. The species is fairly common in this formation, and the free uniserial portions are found broken loose in some abundance.

PLACOPSILINA MINIMA Tappan, n. sp.
Plate 79, figures 10a, b

Test small, attached, early portion coiled, later uniserial; chambers increasing fairly rapidly in size, height about equal to breadth, about four chambers in the coiled portion, with a large umbilical plug protruding above the remainder of the coil; sutures distinct, depressed; wall coarsely arenaceous; aperture an arch on the terminal end, next to the attachment. Length of holotype 0.66 mm., breadth of coil 0.13 mm., breadth of last chamber of uniserial portion 0.15 mm.

Type.—Holotype from locality HTL-13, sample 121.

Remarks.—This species is fairly common in the Duck Creek formation, but no specimens growing free from the attachment have been observed. It is distinguished from *P. longa* Tappan by its much smaller size and higher chambers, which increase more rapidly in size

PLACOPSILINA EXPANSA
Tappan, n. sp.
Plate 79, figure 11

Test medium-sized, attached, compressed, with a small coil at the initial end, then chambers become uniserially arranged and rectilinear; chambers low and broad, increasing gradually in size; sutures indistinct in coiled portion, later distinct and depressed, arched centrally; wall finely arenaceous, with considerable cement; aperture terminal, arching upward from the attached side. Length of holotype 0.65 mm., breadth 0.42 mm., thickness 0.08 mm.

Type—Holotype from locality HTL-27, sample 165.

Remarks—This species differs from *P. longa* Tappan in its smaller size, in the small coiled portion lacking an umbilical plug, and in the very broad and low but arched chambers.

Family LAGENIDAE
Subfamily NODOSARIINAE
Genus DARBYELLA Howe and Wallace, 1933
DARBYELLA SUBCRETACEA Tappan, n.sp.
Plate 79, figures 12a, b

Test medium-sized, early stage planispiral, later chambers to one side of the previous plane of coiling so that 15 chambers may be seen on one side but only 10 on the other, periphery subacute; chambers numerous, low; sutures distinct, slightly raised in the early portion, later depressed; wall calcareous, surface ornamented by seven or eight fine ribs, roughly paralleling the periphery of the later portion of the test, but which may bifurcate or fuse with

other ribs after short distances, ribs most numerous in about the middle portion of the test, thinning out toward the aperture; aperture rounded, slightly below the peripheral angle in the apertural face. Greatest diameter of holotype 0.59 mm., greatest breadth of coiled portion 0.36 mm., thickness 0.17 mm.

Type.—Holotype from locality HTL-34, sample 210.

Remarks,—This species differs from *Robulus costatus* (Fichtel and Moll) in the more elongate and flatter test, more numerous ribs, and in the later chambers being to one side of the previous plane of coiling.

Genus LENTICULINA Lamarck, 1804
LENTICULINA GAULTINA (Berthelin)
Plate 79, figures 13–15b

Cristellaria gaultina BERTHELIN, *1880,* Geol. Soc. France Mém., sér. 3, t. 1, no. 5, p. 49, pl. 3 (26), figs. 15–19.
Lenticulina gaultina, TAPPAN, *1940,* Jour. Paleontology, vol. 14, no. 2, p. 101, pl. 15, figs. 11a, b. Includes additional synonymy.

Test medium-sized, planispiral, sharply keeled; chambers numerous, increasing gradually in size, 12 in the last whorl of the large hypotype, young tests frequently show a proportionately wider face than older specimens, raised umbo present; sutures smooth or slightly elevated near the umbo, very gently curved or nearly straight; wall calcareous, smooth; aperture radiate at the peripheral angle. Greatest diameter of hypotype in figure 13, 1.03 mm., least diameter 0.64 mm., thickness through center 0.32 mm.; greatest diameter of hypotype in figure 14, 0.41 mm., least diameter 0.22 mm., width of apertural face 0.17 mm.; length of specimen in figure 15, 1.13 mm., breadth 0.49 mm., thickness 0.18 mm.

Types.—Hypotypes of figures 13 and 14 from locality HTL-13, sample 112; hypotype of figure 15 from locality HTL-13, sample 121.

Remarks.—This species ranges throughout the Washita group, and is abundant in the Duck Creek. It has also been recorded from France, England, Germany and Western Australia. There is considerable variation in the size and outline of the specimens as well as in the development of the keel. Two of the variations are illustrated, and a few twinned specimens have also been observed.

Genus MARGINULINA d'Orbigny, 1826
MARGINULINA LENTICULINOIDEA
Tappan, n. sp.
Plate 79, figures 19a–20b

Test small, early portion planispiral, later chambers tending to uncoil, sometimes umbonate, periphery usually with a sharp keel; chambers numerous, usually eight or nine in the coiled portion, generally with two uncoiled chambers, which are flattened; sutures distinct, may be raised, slightly curved; wall calcareous, smooth, except for the occasionally slightly raised sutures; aperture radiate, at the peripheral angle. Length of holotype 0.59 mm., breadth of coil 0.41 mm., thickness through center 0.20 mm.; length of paratype 0.66 mm., breadth of coil 0.36 mm., thickness 0.18 mm.

Types.—Holotype from sample 119, paratype from sample 112, both from locality HTL-13.

Remarks.—The early portion resembles *Lenticulina gaultina* (Berthelin) in some respects, but the species differs in possessing fewer chambers per volution, and the specimens never attain the large size of an adult *L. gaultina. Marginulina lenticulinoidea* differs further in possessing the uncoiled portion of the test.

MARGINULINA PAUCICOSTA Tappan,
n. sp.
Plate 79, figures 16a–17b

Test small, elongate, narrow, arcuate; chambers numerous, increasing rapidly in size, height greater than breadth; sutures distinct, depressed, oblique; wall calcareous, surface ornamented by 8 to 10 very low and narrow and widely spaced longitudinal ribs; aperture radiate, terminal, at the end of a slight neck. Length of holotype 0.63 mm., breadth of last chamber 0.11 mm.; length of paratype 0.44 mm., breadth 0.11 mm.

Types.—Holotype and paratype from locality HTL-34, sample 214.

Remarks.—This species differs from *M. tenuissima* (Reuss) in the more tapering initial portion, slender arcuate test, rather than definitely coiled at the base, and in the lower ribs and more oblique sutures.

MARGINULINA PLANITESTA Tappan, n. sp.
Plate 79, figures 18a, b

Test tiny, arcuate or slightly coiled at the base; chambers broad, inflated; sutures distinct, depressed, slightly oblique; wall calcareous, smooth; aperture rounded, terminal. Length of holotype 0.40 mm., breadth 0.08 mm.

Type.—Holotype from locality HTL-13, sample 117.

Remarks.—This species differs from *M. tenuissima* Reuss in the smooth surface and less distinct initial coiling and in lacking the slight neck at the apertural end.

MARGINULINA STRIATIFERA Tappan, n. sp.
Plate 79, figures 26a, b

Test medium-sized, elongate, the coil at the base forming a bluntly rounded initial end; later chambers low, circular in cross section; sutures straight, obscure in early portion, later sutures depressed; wall calcareous, surface ornamented by 24 to 30 very fine and low ribs, which twist slightly about the test; aperture rounded, at the end of a slight neck. Length of holotype 0.65 mm., breadth 0.20 mm.

Type.—Holotype from locality HTL-13, sample 122.

Remarks.—This species is very similar to *M. tenuissima* Reuss, differing only in possessing much more numerous and less elevated longitudinal ribs.

MARGINULINA TENUISSIMA Reuss
Plate 79, figures 21–25b

Marginulina tenuissima REUSS, *1863*, Akad. Wiss. Wien. Sitzungsber., Band 46, p. 70, pl. 7, fig. 13.
Marginulina tenuissima, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 101, pl. 17, figs. 9, 10. Includes additional synonymy.

Test small, elongate, slightly coiled at the base, then with an elongate uniserial portion; chambers numerous, length approximately equal to breadth, nearly circular in section, inflated centrally; sutures distinct, depressed, straight and varying from slightly oblique to nearly horizontal; wall calcareous, surface ornamented by about 9 to 12 longitudinal ribs, which twist slightly about the test; aperture radiate, at the end of a slight neck at the dorsal angle. Length of hypotype in figure 21, 1.29 mm., breadth 0.17 mm.; length of hypotype of figure 22, 0.74 mm., breadth 0.19 mm.; length of hypotype of figure 23, 0.62 mm., breadth 0.20 mm.; length of hypotype of figure 24, 0.65 mm., breadth 0.22 mm.; length of hypotype of figure 25, 0.83 mm., breadth 0.25 mm., thickness 0.22 mm.

Types.—Hypotypes of figures 21, 22 and 24 from locality HTL-27, sample 166; hypotype of figure 23 from locality HTL-57, sample 295; hypotype of figure 25 from locality HTL-13, sample 112.

Remarks.—This species was originally described from Germany, and has been also recorded from England and from the entire Washita group of Texas and Oklahoma. The species is quite variable in size and proportions, some specimens having a large blunt coiled end, and others tapering initially; the amount of inflation of the chambers and the length of the test also vary considerably.

Genus DENTALINA d'Orbigny, 1826
DENTALINA COMMUNIS (d'Orbigny)
Plate 79, figures 28, 29

Nodosaria (*Dentalina*) *communis* D'ORBIGNY, *1826*, Ann. Mag. Nat. Sci., vol. 7, p. 254, no. 35.
Dentalina communis, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 102, pl. 16, fig. 1. Includes additional synonymy.

Test medium-sized, arcuate, elongate and slender; chambers increasing gradually in size, rounded in section, somewhat elongate; sutures distinct, depressed, oblique; wall calcareous, surface smooth; aperture radiate, terminal. Length of hypotype in figure 28, 0.62 mm., breadth 0.13 mm.; length of hypotype in figure 29, 0.89 mm., breadth 0.14 mm.

Types.—Hypotypes both from locality HTL-13, sample 113.

Remarks.—This is a very simple and generalized species and has a very wide geographic and long geologic range. It has been recorded throughout the Cretaceous of Texas.

DENTALINA CYLINDROIDES Reuss
Plate 79, figures 30–31

Dentalina cylindroides REUSS, *1860*, Akad. Wiss. Wien Sitzungsber., Band 40, p. 185, pl. 1, fig. 8.

Dentalina cylindroides, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 102, pl. 16, fig. 2. Includes additional synonymy.

Test large, arcuate, very elongate, fairly thick; chambers numerous, rounded in section, length greater than diameter, initial chamber blunt, last chamber somewhat elongate; sutures distinct but not depressed, straight and horizontal; wall calcareous, surface smooth; aperture terminal, radiate. Length of hypotype of figure 30, 2.39 mm., breadth 0.22 mm.; length of hypotype of figure 31, 0.62 mm., breadth 0.12 mm.

Types.—Hypotype of figure 30 from sample 116, hypotype of figure 31 from sample 117, both from locality HTL-13.

Remarks.—This large species is characterized by the broad cylindrical chambers and unconstricted sutures. It is common throughout the Washita group, having previously been recorded from the Grayson formation of Texas and the range here being extended downward to include the Duck Creek.

DENTALINA sp.
Plate 79, figure 27

Nodosaria filiformis d'Orbigny. CARSEY, *1926*, Texas Univ. Bull. 2612, p. 33, pl. 7, fig. 8.
Dentalina sp. TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 102, pl. 16, figs. 4a, b.

Test small, usually consisting of only two globular to ovate chambers; intervening suture distinct, much constricted; wall calcareous, surface smooth; aperture terminal, rounded. Length of hypotype 0.29 mm., breadth 0.12 mm.

Type.—Hypotype from locality HTL-13, sample 120.

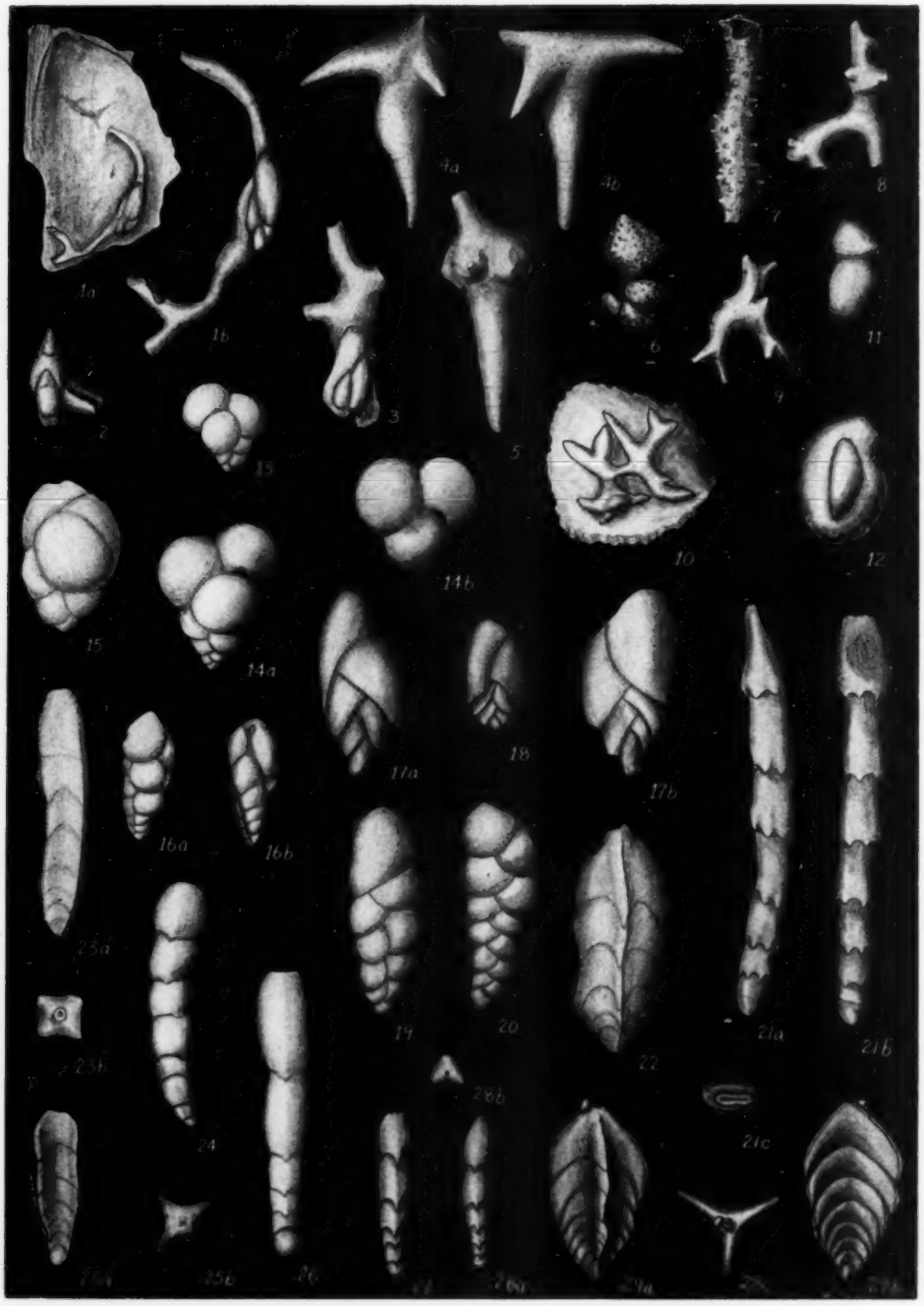
Remarks.—This species occurs throughout the Washita and is probably represented only by fragments of longer specimens, breaking apart at the much constricted sutures.

Genus NODOSARIA Lamarck, 1812
NODOSARIA OBSCURA Reuss
Plate 80, figures 1, 2

EXPLANATION OF PLATE 80
Families Lagenidae to Polymorphinidae

FIGS. *1–2—Nodosaria obscura* Reuss. Side views, ×53. (p. 496)
3, 4—Nodosaria oklahomensis Tappan, n. sp. *3*, Holotype, ×76. *4*, Paratype, ×35. (p. 497)
5—Pseudoglandulina scotti Tappan. ×53. (p. 497)
6—Saracenaria bononiensis striatolipa Tappan, n. var., *6a*, Side view of holotype, *6b*, face view, ×20. (p. 498)
7, 8—Saracenaria callitoecha Tappan, n. sp. *7*, Side view of paratype, *8*, side view of holotype, ×76. (p. 498)
9—Saracenaria cushmani Tappan. *9a*, Side view, *9b*, face view, ×46. (p. 498)
10—Saracenaria duckcreekensis Tappan, n. sp. *10a*, Side view of holotype, *10b*, face view, ×46. (p. 498)
11—Lingulina furcillata Berthelin. *11a*, Side view, *11b*, edge view, ×53. (p. 499)
12, 13—Lingulina nodosaria Reuss. *12*, ×20. *13*, ×53. *12a*, *13a*, Side views, *12b*, *13b*, edge views. (p. 499)
14—Vaginulina complanata perstriata Tappan. Side view, ×35. (p. 499)
15—Vaginulina debilis (Berthelin) Side view, ×35. (p. 500)
16—Vaginulina cf. *debilis* (Berthelin). Side view, ×53. (p. 500)
17, 18—Vaginulina kochii Roemer. *17a*, Side view, *17b*, edge view, ×17. *18*, side view, ×35. (p. 500)
19–21—Vaginulina kochii striolata Reuss. *19*, *21*, ×17. *20*, ×35. All side views. (p. 501)
22—Vaginulina recta Reuss. *22a*, Side view, *22b*, edge view, ×35. (p. 501)
23, 24—Vaginulina raristriata (Chapman). Side views, ×20. (p. 501)
25, 26—Vaginulina tripleura Reuss. *25*, ×76. *26*, Abnormal specimen, showing flabelline tendency, ×46. *25a*, *26a*, *26b*, Side views, *25b*, *26c*, edge views. (p. 501)
27–29—Vaginulina duckcreekensis Tappan, n. sp. *27*, Holotype, *28*, *29*, paratypes, *27b*, edge view, other views from the side, ×17. (p. 500)
30—Flabellinella delicata Loeblich and Tappan? Side view of specimen showing vaginuline stage only, ×46. (p. 503)
31—Lagena apiculata (Reuss). ×53. (p. 503)
32—Lagena striatifera Tappan. *32a*, Side view, *32b*, top view, ×76. (p. 504)
33, 34—Lagena sulcata (Walker and Jacob). *33*, *34a*, Side views, *34b*, top view, ×76. (p. 504)
35—Paleopolymorphina ozawai Tappan. ×76. (p. 504)
36, 37—Globulina exserta (Berthelin). ×53. (p. 504)

Tappan, Lower Cretaceous (Duck Creek) Foraminifera



Tappan, Lower Cretaceous (Duck Creek) Foraminifera

Nodosaria obscura REUSS, *1845–1846*, Verstein. böhm. Kreidef., pt. 1, p. 26, pl. 13, figs. 7–9.
Nodosaria obscura, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 104, pl. 16, figs. 7a–8b. Includes additional synonymy.
Nodosaria harrisi VIEAUX, *1941*, Jour. Paleontology, vol. 15, no. 6, p. 625, pl. 85, fig. 4.
Nodosaria barkeri VIEAUX, *1941*, Jour. Paleontology, vol. 15, no. 6, p. 626, pl. 85, fig. 5.

Test free, medium-sized, chambers in a uniserial and rectilinear series, inflated centrally, increasing rapidly in size as added; sutures fairly distinct, somewhat constricted, horizontal, straight; wall calcareous, surface ornamented with seven to nine thin but highly elevated longitudinal ribs, extending the length of the test, initial extremity with a sharp spine, which is sometimes broken; aperture rounded, terminal on a prominent slender, tubular neck, the end of the chamber usually with a smooth and flattened area surrounding the neck. Length of hypotype in figure 1, 0.71 mm., breadth 0.19 mm.; length of hypotype in figure 2, 0.55 mm., breadth 0.10 mm.

Types.—Hypotype of figure 1 from sample 112, hypotype of figure 2 from sample 113, both from locality HTL-13.

Remarks.—This species is found throughout the Washita group and has been widely recorded elsewhere. In the Washita group, the species is more abundant in the upper formations.

NODOSARIA OKLAHOMENSIS Tappan, n. sp.
Plate 80, figures 3, 4

Test small, uniserial, rectilinear; chambers elongate, of approximately same diameter throughout the length of the test; sutures distinct, constricted; wall calcareous, surface ornamented by 8 to 10 low longitudinal ribs; aperture terminal, simple. Length of holotype 0.38 mm., breadth 0.66 mm.; length of paratype 0.88 mm., breadth 0.11 mm.

Types.—Holotype of figure 3 from sample 120, paratype of figure 4 from sample 116, both from locality HTL-13.

Remarks.—This species differs from *N. obscura* Reuss in the lower ribs, more constricted sutures, narrower test and equal-sized chambers throughout.

Genus PSEUDOGLANDULINA Cushman, 1929

PSEUDOGLANDULINA SCOTTI Tappan
Plate 80, figures 5a–b

Pseudoglandulina scotti TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 105, pl. 16, figs. 13a, b.

Test medium-sized, elongate, tapering at the initial end; chambers wider than long, increasing rapidly in size at first, then more slowly, so that the adult test has nearly

EXPLANATION OF PLATE 81
Families Polymorphinidae to Buliminidae

FIGS. *1–3—Globulina redriverensis* Tappan, n. sp. *1a*, Holotype, showing attachment, ×10. *1b*, Enlarged, ×20. *2*, *3*, Paratypes, ×20. (p. 505)
4, *5—Pseudopolymorphina roanokensis* Tappan. ×76. (p. 506)
6, *7—Ramulina aculeata* Wright. *6*, Specimen with globular chambers. *7*, Stoloniferous type, ×20. (p. 506)
8, *9—Ramulina globulifera* Brady. ×35. (p. 506)
10—Bullopora cervicornis (Chapman). Specimen showing attachment, ×10. (p. 506)
11, *12—Bullopora laevis* (Sollas). *11*, ×41. *12*, ×17. (p. 507)
13, *14—Gümbelitria harrisi* Tappan. *13*, *14a*, Side views, *14b*, top view, ×117. (p. 507)
15—Bulimina nannina Tappan. Side view, ×117. (p. 507)
16—Neobulimina minima Tappan. ×117. (p. 507)
17, *18—Virgulina croneisi* Tappan, n. sp. *17*, Holotype, *18*, paratype, ×117. (p. 508)
19, *20—Virgulina minuta* Cushman. ×117. (p. 508)
21—Unicosiphonia subcretacea Tappan, n. sp. *21a*, *b*, Side views of holotype, *21c*, top view, ×46. (p. 508)
22—Dentalinopsis excavata (Reuss). ×46. (p. 509)
23—Dentalinopsis märtensi (Reuss). *23a*, Side view, *23b*, top view, ×76. (p. 509)
24—Dentalinopsis nodosaria Tappan, n. sp. Holotype, ×53. (p. 509)
25—Dentalinopsis quadrata Vieaux. *25a*, Side view, *25b*, top view, ×27. (p. 509)
26–28—Dentalinopsis chapparsi Tappan, n. sp. *26*, *27*, Side views of paratypes, *28a*, side view of holotype, *28b*, top view. *26*, ×76. *27*, *28*, ×46. (p. 509)
29—Dentalinopsis tricarinatum acutangulum Reuss. *29a*, *29b*, Side views, *29c*, top view, ×46. (p. 510)

parallel sides; sutures distinct, slightly depressed; wall calcareous, surface smooth; aperture terminal, radiate. Length of hypotype 0.52 mm., breadth 0.16 mm.

Type.—Hypotype from locality HTL-13, sample 116.

Remarks.—This species was originally described from the Grayson formation, and the range is here extended downward to include the Duck Creek formation.

Genus SARACENARIA Defrance, 1824

SARACENARIA BONONIENSIS STRIATOLIPA Tappan, n. var.

Plate 80, figures 6a, b

Test medium-sized, elongate, early portion close-coiled, later portion arcuate, tending to become rectilinear; chambers increasing rapidly in height, triangular in cross section; sutures slightly curved, convex upward, oblique, distinct, very slightly depressed; wall calcareous, smooth, a faint keel along the three angles of the test; aperture radiate, at the peripheral angle. Length of holotype 1.18 mm., breadth of side 0.26 mm., breadth of ventral face 0.25 mm.

Type.—Holotype from locality HTL-13, sample 117.

Remarks.—This variety differs from *S. bononiensis* (Berthelin) in the somewhat larger size and in lacking a rib down the center of the ventral face. The true *S. bononiensis* has also been recorded from the Washita group.

SARACENARIA CALLITOECHA Tappan, n. sp.

Plate 80, figures 7, 8

Test small, elongate, early portion close-coiled, later portion arcuate, tending to become rectilinear; chambers increasing gradually in height, triangular in section, sutures gently curved, convex upward, oblique, very slightly depressed; wall calcareous, surface ornamented by longitudinal keels down the three angles of the test, by two longitudinal ribs down the ventral face, which die out part of the way up the last chamber, and by two ribs on each side, roughly paralleling the ventral margins, and closer to the ventral face; aperture radiate, at the end of a slight neck. Length of holotype 0.46 mm., breadth of side 0.13 mm., breadth of ventral face 0.125 mm.; length of paratype 0.47 mm., breadth of side 0.12 mm.

Types.—Holotype and paratype from locality HTL-13, sample 120.

Remarks—This species differs from *S. vestita* (Berthelin) in the more closely coiled initial portion, in having only two ribs on each side, and in possessing the ventral ribs. Furthermore, the ribs on the sides of *S. callitoecha* begin at the coil, and continue for nearly the entire length of the test, while in *S. vestita* (Berthelin) only a few of the ribs begin at the coil, and, after crossing the test transversely, one rib dies out at the apertural end of each chamber, new ones being inserted more ventrally to take their place.

SARACENARIA CUSHMANI Tappan

Plate 80, figures 9a, b

Saracenaria cushmani TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 106, pl. 16, figs. 17a, b.

Test medium-sized to small, close-coiled in the early portion, later tending somewhat to uncoil; chambers increasing gradually in size, triangular in section, inflated sharply just in front of the depressed sutures so that the appearance of limbate sutures is obtained, occasionally the inflation may be sufficiently sharp to give the appearance of a surficial rib, peripheral keel present, test slightly umbonate; sutures distinct, depressed, curved, convex toward the aperture; wall calcareous; aperture at the peripheral angle and raised slightly on a short neck, apertural face broad. Length of hypotype 0.51 mm., breadth of coil 0.22 mm., breadth of side 0.23 mm., breadth of ventral face 0.22 mm.

Type.—Hypotype from locality HTL-13, sample 119.

Remarks.—This species was originally described from the Grayson formation, and ranges throughout the Washita group.

SARACENARIA DUCKCREEKENSIS Tappan, n. sp.

Plate 80, figures 10a, b

Test comparatively large, elongate, triangular in section; early portion close-coiled, later chambers uncoiled and rectilin-

ear, coiled portion small, then chambers increase rapidly in size for a short distance, slightly inflated just in front of the sutures, and regularly inflated on the ventral face, a longitudinal keel present on each of the three angles, that of the dorsal angle being very high, thin and fragile, and occasionally broken, giving the test a ragged edge; sutures distinct, slightly depressed; wall calcareous; aperture radiate, at the peripheral angle. Length of holotype 0.77 mm. breadth of side 0.25 mm., breadth of ventral face 0.27 mm.

Type.—Holotype from locality HTL-57, sample 295.

Remarks.—This species differs from *S. bononiensis* (Berthelin) in the larger size, much wider apertural face, which lacks the longitudinal rib, and in having more highly inflated chambers.

Genus LINGULINA d'Orbigny, 1826
LINGULINA FURCILLATA Berthelin
Plate 80, figures 11a, b

Lingulina furcillata BERTHELIN, *1880*, Soc. geol. France Mém., sér. 3, t. 1, no. 5, p. 65, pl. 4 (27), figs. 6a–c.
Lingulina furcillata, EGGER, *1899*, Bayer. Akad. Wiss. München, Abh., Cl. II, Band 21, p. 85, pl. 23, figs. 28–30.
Lingulina furcillata, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no., 2, p. 106, pl. 16, figs. 18a–c.

Test elongate, flattened, uniserial, rectilinear; proloculum ovate, later chambers low and broad at first, increasing in height as added, arched centrally; sutures distinct, depressed, arched upward in the center of the test, V-shaped on the edges of the test; wall calcareous, surface smooth; aperture terminal, elongate. Length of hypotype 0.43 mm., breadth 0.11 mm., thickness 0.07 mm.

Types.—Hypotype from locality HTL-13, sample 118.

Remarks.—This species was described from France and has also been recorded from Germany. It has been found in the Grayson formation of Texas and the range in this area is here extended downward to include the Duck Creek.

LINGULINA NODOSARIA Reuss
Plate 80, figures 12a–13b

Lingulina nodosaria REUSS, *1863*, Akad. Wiss. Wien Sitzungsber., Band 46, p. 59, pl. 5, fig. 12.
Lingulina nodosaria, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 107, pl. 16, figs. 20a, b. Includes additional synonymy.

Test elongate, compressed, uniserial, rectilinear; proloculum globular, second chamber generally low, followed by a much higher chamber, the remainder increasing gradually in size; sutures distinct, depressed, arched gently upward over the center of the test; wall calcareous, smooth; aperture elongate, terminal, earlier apertures generally visible through the wall of the translucent test, giving an appearance characteristic of the species. Length of hypotype in figure 12, 0.92 mm., breadth 0.22 mm., thickness 0.15 mm.; length of hypotype in figure 13, 0.48 mm., breadth 0.21 mm., thickness 0.12 mm.

Types.—Hypotype of figure 12 from locality HTL-34, sample 217; hypotype of figure 13 from locality HTL-57, sample 295.

Remarks.—This species occurs throughout the Washita group of Texas and Oklahoma and is also known from England, France and Germany.

Genus VAGINULINA d'Orbigny, 1826
VAGINULINA COMPLANATA PERSTRIATA Tappan
Plate 80, figure 14

Vaginulina complanata perstriata TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 108, pl. 16, fig. 25.

Test small, flattened, broad, coiled at the base, later chambers tending to uncoil; sutures slightly depressed, curved, convex upward, oblique; wall calcareous, surface ornamented by numerous fine ribs running obliquely from the ventral to the dorsal margin; aperture radiate, at the peripheral angle. Length of hypotype 0.76 mm., breadth 0.35 mm., thickness 0.11 mm.

Type.—Hypotype from locality HTL-34, sample 214.

Remarks.—This variety of Reuss' species was originally described from the Grayson formation and the range is here extended downward to include the Duck Creek formation.

VAGINULINA DEBILIS (Berthelin)
Plate 80, figure 15

Marginulina debilis BERTHELIN, *1880*, Soc. géol. France Mém., sér. 3, t. 1, no. 5, p. 3, pl. 3 (26), fig. 28.
Vaginulina debilis, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 108, pl. 16, figs. 26a, b. Includes additional synonymy.

Test medium to small, elongate, arcuate, slender, tapering, subtriangular in section; chambers inflated ventrally toward their bases, tapering toward the aperture, increasing in height as added, ventral side wide, margins angular, resulting in a triangular section; sutures distinct, depressed, oblique, highest at the concave dorsal margin; wall calcareous, surface smooth; aperture radiate, at the dorsal angle, which is produced and necklike in appearance. Length of hypotype 0.95 mm., breadth 0.99 mm.

Type.—Hypotype from locality HTL-13, sample 119.

Remarks.—This species was originally described from France and has been recorded from England and Germany, and from the Grayson and Denton formations of Texas. The range in the Gulf Coast area is here extended downward to include the Duck Creek formation.

VAGINULINA sp. cf. V. DEBILIS (Berthelin)
Plate 80, figure 16

Test elongate, narrow, early chambers slightly coiled, later rectilinear, chambers elongate, inflated ventrally; sutures distinct, depressed, oblique; wall calcareous, surface smooth; aperture terminal, at the dorsal angle. Length of hypotype 0.65 mm., breadth of last chamber 0.08 mm.,

Type.—Hypotype from locality HTL-13, sample 113.

Remarks.—This species may be only a microspheric form of *V. debilis* (Berthelin) as it is similar in many features. It differs in the straight rather than curved dorsal margin and in the more distinct coil at the base, and in having a globular rather than a basally pointed proloculum.

VAGINULINA DUCKCREEKENSIS Tappan, n. sp.
Plate 80, figures 27a–29

Test large, broad, elongate, sides flat and parallel, periphery concave; chambers low, oblique, increasing gradually in size from the elongate-oval proloculum, which has a concave surface, rather than being globular and inflated; sutures distinct, slightly raised, oblique; wall calcareous, surface smooth and slightly concave, except for the raised sutures and low keels at the angles of the test; aperture radiate, at the dorsal angle. Length of holotype 2.77 mm., breadth 0.45 mm., thickness 0.17 mm., thickness through proloculum 0.13 mm.; length of paratype of figure 28, 2.13 mm., breadth 0.45 mm.; length of paratype of figure 29, 0.67 mm., breadth 0.17 mm.

Types.—Holotype and paratypes from locality HTL-34, sample 210.

Remarks.—This species is similar in general appearance to *V. kochii* Roemer, and the two species may have been confused. The present species differs mainly in the character of the proloculum, which is quite elongate, basally pointed, and with concave sides, while that of *V. kochii* as well as *V. recta* Reuss is much inflated above the remainder of the test, and is globular in outline. The sutures of *V. duckcreekensis* are also less elevated and the sutures more oblique.

VAGINULINA KOCHII Roemer
Plate 80, figures 17a–18

Vaginulina kochii ROEMER, *1840–1841*, Verstein. norddeutsch. Kreidef., p. 96, pl. 15, fig. 10.
Vaginulina kochii, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 109, pl. 17, figs. 2–4. Includes additional synonymy.

Test large, compressed, elongate-triangular in side view, sides parallel, periphery slightly concave, peripheral angles carinate; chambers increasing gradually in size from the globular proloculum, which is raised above the plane surface of the remainder of the test, chambers broad and low; sutures distinct, thickened and raised, strongly oblique, curved, convex upward; wall calcareous, surface smooth; aperture radiate at the dorsal angle of the test. Length of microspheric hypotype in figure 17, 2.95 mm., breadth 0.56 mm.; length of megalospheric hypotype of figure 18, 0.31 mm., breadth 0.18 mm., thickness through proloculum 0.20 mm., thickness through chambers 0.11 mm.

Types.—Hypotype of figure 17 from locality HTL-13, sample 121; hypotype of figure 18 from locality HTL-34, sample 218.

Remarks.—This species occurs abundantly throughout the Washita group, and has also been observed in Germany, France, and England.

VAGINULINA KOCHII STRIOLATA Reuss
Plate 80, figures 19–21

Vaginulina striolata REUSS, *1863*, Akad. Wiss. Wien Sitzungsber., Band 46, pt. 1, p. 45, pl. 3, fig. 7.
Vaginulina kochii striolata, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 110, pl. 17, fig. 5. Includes additional synonymy.

This variety differs from *V. kochii* Roemer in the presence of a variable number of obliquely transverse striations cutting the raised sutures into a series of short, oblique ridges, which may continue as ribs across the chambers, the amount of ornamentation varying considerably in different specimens. Length of microspheric specimen in figure 19, 2.09 mm., breadth 0.58 mm.; length of megalospheric specimen in figure 20, 0.53 mm., breadth 0.27 mm., thickness through proloculum 0.22 mm., thickness through center of chamber 0.19 mm., thickness at edge of chamber 0.10 mm.; length of microspheric specimen in figure 21, 1.78 mm., breadth 0.52 mm., thickness 0.17 mm.

Types.—Hypotype of figure 19 from locality HTL-13, sample 116; hypotype of figure 20 from locality HTL-34, sample 218; hypotype of figure 21 from locality HTL-57, sample 296.

Remarks.—This species ranges throughout the Washita group and has also been observed in England, France, and Germany.

VAGINULINA RARISTRIATA (Chapman)
Plate 80, figures 23–24

Nodosaria (*Dentalina*) *raristriata* CHAPMAN, *1893*, Royal Micr. Soc. Jour., p. 591, pl. 7 (9), fig. 4.

Test large, elongate, arcuate, tapering, triangular in section; chambers increasing in size as added, inflated ventrally, elongate; sutures oblique, depressed on the ventral margin, otherwise not distinct; wall calcareous, surface ornamented by numerous fine transverse ribs crossing the chambers; aperture terminal at the dorsal angle. Length of hypotype of figure 23, 1.55 mm., breadth 0.17 mm.; length of hypotype of figure 24, 1.81 mm., greatest breadth 0.24 mm., thickness 0.15 mm.

Types.—Hypotype of figure 23 from sample 119, hypotype of figure 24 from sample 120, both from locality HTL-13.

Remarks.—This species is somewhat similar to *Vaginulina debilis* (Berthelin) in general features, but differs in the larger size, less inflation of the chambers and in the presence of the transverse ribs on the surface. Chapman described the species as a *Nodosaria* but this specimen was definitely arcuate. His illustration does not show quite as definite a triangular section, but the specimens are probably the same species.

VAGINULINA RECTA Reuss
Plate 80, figures 22a–b

Vaginulina recta REUSS, *1863*, Akad. Wiss. Wien Sitzungsber, Band 46, p. 48, pl. 3, figs. 14, 15.
Vaginulina recta, SCHMITT, *1929*, Zeitsch. f. Geschiebef., Band 5, Heft 3, pl. 5, fig. 21.
Vaginulina recta, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 110, pl. 17, figs. 7a–8. Includes additional synonymy.

Test elongate, narrow, compressed, sides parallel, periphery slightly concave; chambers numerous, increasing very gradually in size from the globular proloculum, which protrudes somewhat above the surface of the remainder of the test, increase in size sufficiently gradual that the edges of the test are generally subparallel; sutures distinct, raised, oblique; wall calcareous, surface smooth, except for the raised sutures; aperture radiate, at the dorsal angle, which is produced into a slight neck. Length of hypotype 0.89 mm., breadth 0.19 mm., thickness through proloculum 0.12 mm., thickness of later chambers 0.10 mm.

Type.—Hypotype from locality HTL-13, sample 119.

Remarks.—This species occurs throughout the Washita group but is somewhat less common than is *V. kochii* Roemer.

VAGINULINA TRIPLEURA (Reuss)
Plate 80, figures 25a–26c

Cristellaria tripleura REUSS, *1860*, Akad. Wiss. Wien Sitzungsber., Band 40, p. 211, pl. 9, fig. 5.
Vaginulina tripleura, TAPPAN, *1940*, Jour. Paleon-

tology, vol. 14, no. 2, p. 111, pl. 17, figs. 11a–12b. Includes additional synonymy.

Test small, flattened, early portion slightly coiled, later chambers uncoiling, periphery rounded; chambers numerous; sutures distinct, depressed, quite oblique; wall calcareous, surface smooth; aperture radiate at the peripheral angle. Length of hypotype in figure 25, 0.52 mm., breadth 0.13 mm., greatest thickness 0.07 mm.; length of hypotype in figure 26, 0.48 mm., breadth 0.26 mm., thickness 0.13 mm.

Types.—Hypotype of figure 25 from locality HTL-13, sample 120; hypotype of figure 26 from locality HTL-34, sample 218.

Remarks.—This species ranges throughout the Washita group and is quite variable in size and proportions. The specimen in figure 26 shows a freakish development of the last chamber, tending toward *Palmula* in character.

Genus PALMULA Lea, 1833

PALMULA ACUTA Loeblich and Tappan[2]

Palmula acuta LOEBLICH and TAPPAN, *1941*, Bull. Am. Paleontology, vol. 26, no. 99, p. 7, pl. 1, figs. 3, 4.

Types.—Holotype from locality HTL-34, sample 210; paratypes from locality HTL-34, sample 211 and locality HTL-27, sample 169.

PALMULA HOWEI Loeblich and Tappan

Palmula howei LOEBLICH and TAPPAN, *1941*, Bull. Am. Paleontology, vol. 26, no. 99, p. 9, pl. 2, figs. 4–7.

Types.—Holotype from the Duck Creek formation at locality HTL-57, sample 296; paratypes from the middle Duck Creek at the same locality, the middle and upper Duck Creek at locality HTL-13, the upper Duck Creek at localities HTL-34, and HTL-35, and from the Fort Worth formation.

PALMULA LEAI Loeblich and Tappan

Palmula leai LOEBLICH and TAPPAN, *1941*, Bull. Am. Paleontology, vol. 26, no. 99, p. 10, pl. 1, figs. 1–2.

Types.—Holotype from locality HTL-34, sample 210; paratypes from locality HTL-34, sample 211, and from the lower and middle Duck Creek at locality HTL-27.

PALMULA LEPTATA Loeblich and Tappan

Palmula leptata LOEBLICH and TAPPAN, *1941*, Bull. Am. Paleontology, vol. 26, no. 99, p. 11, pl. 2, fig. 2.

Types.—Holotype from locality HTL-34, sample 211; paratype from locality HTL-27, sample 165.

Genus FRONDICULARIA Defrance, 1826

FRONDICULARIA HILLI Loeblich and Tappan

Frondicularia hilli LOEBLICH and TAPPAN, *1941*, Bull. Am. Paleontology, vol. 26, no. 99, p. 15, pl. 3, figs. 2, 3.

Types.—Holotype and paratype from locality HTL-34, sample 210.

FRONDICULARIA UNGERI Reuss

Frondicularia ungeri REUSS, *1863*, Akad. Wiss. Wien Sitzungsber., Band 46, p. 54, pl. 4, figs. 11a, b.

Frondicularia ungeri, LOEBLICH and TAPPAN, *1941*, Bull. Am. Paleontology, vol. 26, no. 99, p. 16, pl. 3, figs. 5–7. Includes additional synonymy.

Types.—Hypotypes from the Duck Creek at locality HTL-13; hypotypes also from the Weno, Paw Paw and Grayson formations of the Washita. The type locality is in Germany, and the species has also been recorded from England, France and Western Australia.

FRONDICULARIA sp. A. Loeblich and Tappan

Frondicularia sp. *A.* LOEBLICH and TAPPAN, *1941*, Bull. Am. Paleontology, vol. 26, no. 99, p. 17, pl. 3, fig. 9.

Types.—Hypotypes from locality HTL-57, sample 296; and from locality HTL-13, sample 119.

FRONDICULARIA sp. B. Loeblich and Tappan

Frondicularia sp. *B.* LOEBLICH and TAPPAN, *1941*, Bull. Am. Paleontology, vol. 26, no. 99, p. 18, pl. 3, fig. 8.

[2] The species of *Palmula*, *Frondicularia* and *Flabellinella* from the Duck Creek formation were recently illustrated and described (Loeblich and Tappan, 1941) and are merely listed, with the reference and type localities, but neither illustrated nor described herein.

Type.—Hypotype from locality HTL-27, sample 169.

Genus FLABELLINELLA Schubert, 1900
FLABELLINELLA DELICATA Loeblich and Tappan

Flabellinella delicata LOEBLICH and TAPPAN, *1941*, Bull. Am. Paleontology, vol. 26, no. 99, p. 18, pl. 2, figs. 17–19.

Types.—Holotype from locality HTL-34, sample 213; paratypes from sample 212 and 216 at the same locality, and from the lower and middle Duck Creek at locality HTL-13, and from the Middle Duck Creek at locality HTL-57.

FLABELLINELLA DELICATA Loeblich and Tappan?
Plate 80, figure 30

Test small, flattened, elongate, chambers increasing gradually in size from the globular and raised proloculum; sutures distinct, depressed, oblique; wall calcareous, surface smooth; aperture radiate, at the dorsal angle. Length of hypotype 0.52 mm. breadth 0.12 mm., thickness 0.06 mm.

Type.—Hypotype from locality HTL-13, sample 119.

Remarks.—This species is somewhat similar in outline to *Vaginulina kochii* Roemer, but differs in the much smaller and more delicate test and in possessing depressed rather than raised sutures. It is here referred to the early stage of *Flabellinella delicata* Loeblich and Tappan, which it closely resembles. The original description of *Flabellinella delicata* stated that

> . . . no *Vaginulina* similar to the early stages of this species has been found to occur with it. While this species occurs in the Duck Creek formation, a *Vaginulina* similar to its early stage occurs in the much younger Paw Paw formation, but no *Fabellinella* stage is found in the Paw Paw, comparable to the Duck Creek species.

The present specimen and a few others have since been found and may represent the early *Vaginulina* stage of the species, although no adult *Flabellinella delicata* has been found with an early *Vaginulina* stage of a length equal to that of the free *Vaginulina*-like forms. Perhaps the latter are megalospheric tests, and only the microspheric tests show the complete development.

FLABELLINELLA PLANA Loeblich and Tappan

Flabellinella plana LOEBLICH and TAPPAN, *1941*, Bull. Am. Paleontology, vol. 26, no. 99, p. 19, pl. 2, figs. 13–15.

Types.—Holotype and paratypes from locality HTL-38, sample 224; paratypes also from locality HTL-35, sample 277; and from the middle Duck Creek at localities HTL-13 and HTL-27, the lower and middle Duck Creek at locality HTL-34, and the lower Duck Creek at localities HTL-57 and HTL-60.

FLABELLINELLA PLANA STRIATA Loeblich and Tappan

Flabellinella plana striata LOEBLICH and TAPPAN, *1941*, Bull. Am. Paleontology, vol. 26, no. 99, p. 21, pl. 2, fig. 16.

Types.—Holotype from locality HTL-13, sample 119; paratype from locality HTL-34, sample 215.

FLABELLINELLA? sp. Loeblich and Tappan

Flabellinella? sp. LOEBLICH and TAPPAN, *1941*, Bull. Am. Paleontology, vol. 26, no. 99, p. 21, pl. 3, fig. 1.

Types.—Hypotypes from locality HTL-13, sample 119, and locality HTL-34, sample 210.

Subfamily LAGENINAE
Genus LAGENA Walker and Jacob, 1798
LAGENA APICULATA (Reuss)
Plate 80, figure 31

Oolina apiculata REUSS, *1850*, Haidinger's Nat. Abhandl., vol. 4, p. 22, pl. 1, fig. 1.
Lagena apiculata, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 111, pl. 17, figs. 15a, b. Includes additional synonymy.

Test tiny, consisting of a single ovate chamber, widest toward the base, with an initial spine; wall calcareous, surface smooth; aperture rounded, terminal, at the end of a short, wide neck. Length of hypotype 0.34 mm., breadth 0.18 mm.

Type.—Hypotype from locality HTL-35, sample 215.

Remarks.—This species occurs throughout the Washita group and has been widely recorded from other strata.

LAGENA STRIATIFERA Tappan
Plate 80, figures 32a, b

Lagena striatifera TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 112, pl. 17, figs. 18a, b.

Test tiny, consisting of a single ovate chamber, widest slightly below the center with a blunt basal spine; wall calcareous, surface ornamented with about 28 very fine, low ribs; aperture terminal, simple, at the end of a short broad neck. Length of hypotype 0.25 mm., breadth 0.16 mm.

Type.—Hypotype from locality HTL-13, sample 113.

Remarks.—This species was originally described from the Grayson formation and the geologic range is here extended downward to include the Duck Creek formation.

LAGENA SULCATA (Walker and Jacob)
Plate 80, figures 33–34b.

Serpula (*Lagena*) *sulcata* WALKER and JACOB, *1798*, Adam's Essays, Kanmacher's Edit., p. 634, pl. 14, fig. 5.
Lagena sulcata, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 112, pl. 17, figs. 19a, b. Includes additional synonymy.

Test tiny, consisting of a single flask-shaped chamber; wall calcareous, surface ornamented by 10 to 12 longitudinal ribs, usually with a basal spine as well; aperture radiate, at the end of a long neck, the base of which may be somewhat thickened and striate, but both neck and basal spine may be broken away. Length of hypotype in figure 33, 0.24 mm., breadth 0.17 mm.; length of hypotype in figure 34, 0.18 mm., breadth 0.15 mm.

Types.—Hypotype of figure 33 from sample 218, hypotype of figure 34 from sample 214, both from locality HTL-34.

Remarks.—This species ranges throughout the Washita group and has also been widely recorded elsewhere.

Family POLYMORPHINIDAE
Subfamily POLYMORPHININAE
Genus PALEOPOLYMORPHINA Cushman and Ozawa, 1930
PALEOPOLYMORPHINA OZAWAI Tappan
Plate 80, figure 35

Paleopolymorphina ozawai TAPPAN, *1940*, Jour. Paleontology, vol. 14; no. 2, p. 113, pl. 17, figs. 20a–21c.

Test tiny, slightly elongate, early chambers spiral, later ones biserial, chambers inflated, elongate, later ones generally much enlarged, overhanging over earlier chambers; sutures indistinct in early portion, in biserial portion distinctly depressed; wall calcareous, surface smooth; aperture radiate, terminal. Length of hypotype 0.29 mm., breadth 0.15 mm., thickness 0.11 mm.

Type.—Hypotype from locality HTL-34, sample 218.

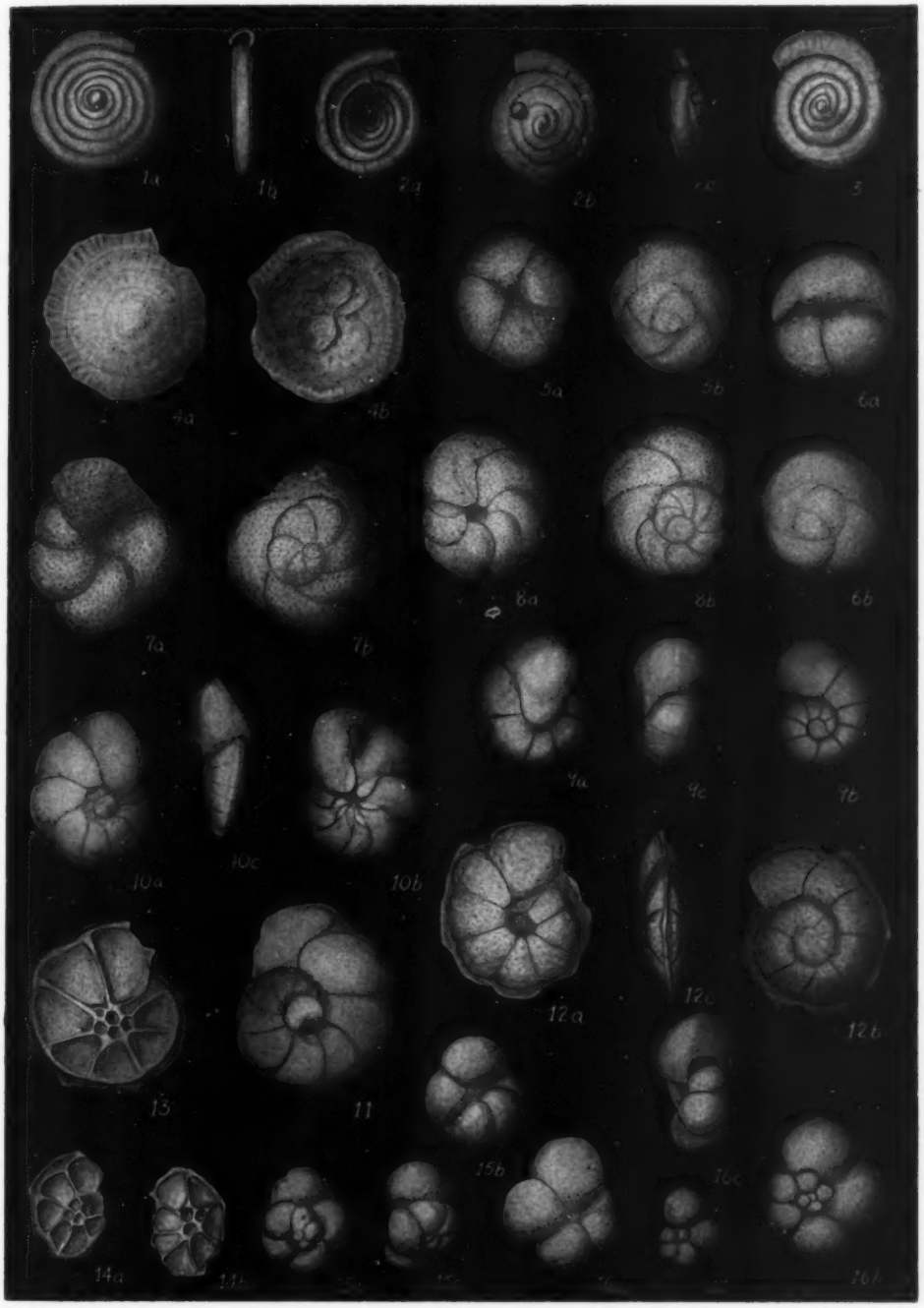
Remarks.—This species was originally described from the Grayson formation, and the range is here extended downward to include the Duck Creek formation.

Genus GLOBULINA d'Orbigny, 1839
GLOBULINA EXSERTA (Berthelin)
Plate 80, figures 36a–37

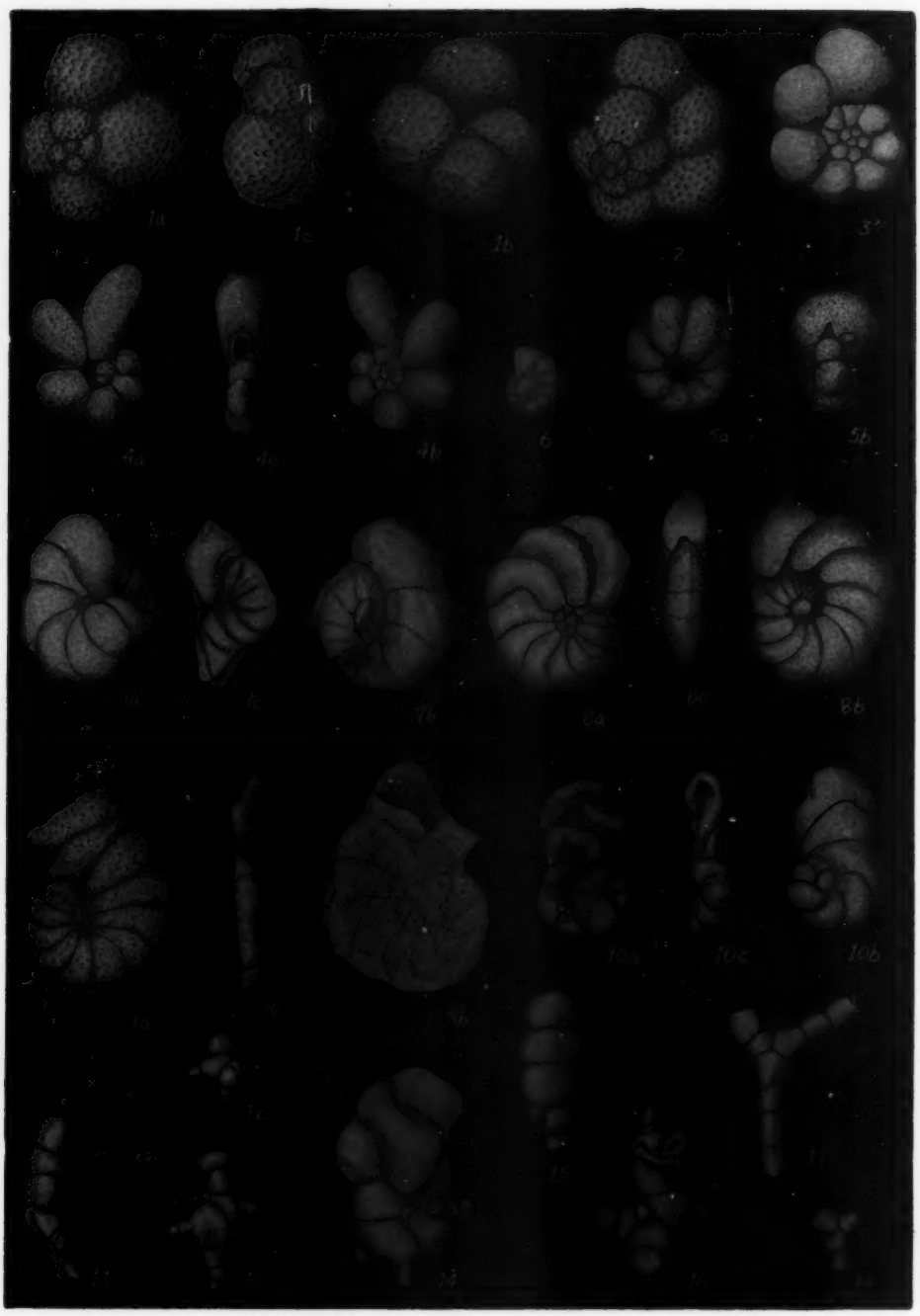
Polymorphina exserta BERTHELIN, *1880*, Soc. géol.

EXPLANATION OF PLATE 82
Families Spirillinidae to Globigerinidae

FIG. *1—Spirillina minima* Schacko. *1a*, Side view, *1b*, edge view, ×76. (p. 510)
2, 3—Turrispirillina subconica Tappan, n. sp. *2a*, *2b*, Side views of holotype, *2c*, edge view, ×53. *3*, Side view of paratype, ×76. (p. 510)
4—Patellina subcretacea Cushman and Alexander. *4a*, Dorsal view, *4b*, ventral view, ×128. (p. 511)
5, 6—Discorbis minutissima Tappan, n. sp. *5*, Holotype, *6*, paratype, *5a*, *6a*, ventral views, *5b*, *6b*, dorsal views, ×117. (p. 511)
7, 8—Discorbis minima Vieaux. *7a*, *8a*, Ventral views, *7b*, *8b*, dorsal views, ×53. (p. 511)
9—Gyroidina loetterlei Tappan. *9a*, Ventral view, *9b*, dorsal view, *9c*, edge view, ×76. (p. 512)
10, 11—Valvulineria asterigerinoides Plummer. *10a*, *11*, Dorsal views, *10b*, ventral view, *10c*, edge view, ×53. (p. 511)
12—Epistomina lenticularia Tappan, n. sp. *12a*, Ventral view of holotype, *12b*, dorsal view, *12c*, edge view, ×27. (p. 512)
13, 14—Epistomina limbata Tappan, n. sp. *13*, Paratype, *14*, holotype, ×27. (p. 512)
15—Globigerina graysonensis Tappan. *15a*, Dorsal view, *15b*, ventral view, *15c*, edge view, ×117. (p. 513)
16, 17—Globigerina cretacea d'Orbigny. *16a*, Ventral view, *16b*, *17*, dorsal views, *16c*, edge view, ×53. (p. 512)



Tappan, Lower Cretaceous (Duck Creek) Foraminifera



Tappan, Lower Cretaceous (Duck Creek) Foraminifera

France Mém., sér. 3, t. 1, no. 5, p. 57, pl. 4, figs. 22a–23b.
Polymorphina bucculenta BERTHELIN, *1880*, idem, p. 58, pl. 4, figs. 16a–17b.
Globulina exserta, CUSHMAN and OZAWA, *1930*, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 78, pl. 19, figs. 5–7.

Test medium to small, ovate, initial end usually somewhat produced; chambers slightly inflated, arranged in a nearly triserial series; sutures vary from slightly depressed to indistinct; wall calcareous, surface smooth; aperture radiate, terminal. Length of hypotype in figure 36, 0.31 mm., breadth 0.15 mm.; length of hypotype in figure 37, 0.45 mm., breadth 0.23 mm.

Types.—Hypotypes from locality HTL-13, sample 112.

Remarks.—The hypotypes here figured are somewhat smaller than the limits given by Cushman and Ozawa but are similar in all other features. They are representative of the two variations found by Berthelin, the specimen in figure 12 being the type which he named *Polymorphina exserta*, that of figure 13 being the type called *P. bucculenta*. Cushman and Ozawa did not consider the variation in the two types to be of specific rank, and therefore, combined them under Berthelin's specific name of *exserta*, changing the generic designation to *Globulina*. They list the species as very common in the Cretaceous of England and France and have also recorded it from the Goodland formation (Fredericksburg group) of northern Texas. The range is here extended upward into the Duck Creek formation of the Washita group.

GLOBULINA REDRIVERENSIS Tappan, n. sp.
Plate 81, figures 1a–3

Test large, early portion free, more or less compressed, ovate in outline, later portion attached and consisting of a fistulose growth beginning at the aperture of the globuline portion and spreading widely over the attachment, irregularly bifurcating at intervals; chambers arranged in a nearly triserial series, elongate, slightly inflated; sutures of globuline portion obscure or faintly depressed; wall calcareous, surface smooth; aperture at the open ends of the attached tubular growth. Length of holotype 2.02 mm., length of globuline portion 0.50 mm., greatest breadth 0.30 mm.; length of globuline portion of paratype in figure 3, 0.51 mm. breadth 0.22 mm.; length of globuline portion of paratype in figure 2, 0.65 mm., breadth 0.29 mm.

Types.—Holotype and paratype of figure 2 from sample 120, paratype of figure 3 from sample 117, all from locality HTL-13.

Remarks.—This species differs from *G. exserta* (Berthelin) in the attached character, in the somewhat more elongate globuline portion, and in the presence of the very elongate, branching fistulose growth. Attached species of the Polymorphininae are extremely rare, probably less than half a dozen having been recorded to date. The attached area of *Globulina redriverensis* is elongate and quite conspicuous, and thus differs from that of the earlier described attached species, all of which have only an

EXPLANATION OF PLATE 83

Families Globigerinidae to Anomalinidae

FIGS. *1, 2—Globigerina washitensis* Carsey. *1a, 2*, Dorsal views, *1b*, ventral view, *1c*, edge view, ×53. (p. 513)
3—Globigerina planispira Tappan. ×53. (p. 513)
4—Hastigerinella subcretacea Tappan, n. sp. *4a*, Ventral view of holotype, *4b*, dorsal view, *4c*, edge view, ×53. (p. 513)
5—Globigerinella cushmani Tappan, n. sp. *5a*, Side view of holotype, *5b*, edge view, ×53. (p. 513)
6–8—Anomalina plummerae Tappan. *6, 7b, 8b*, Dorsal views, *7a, 8a*, ventral views, *7c, 8c*, edge views, ×35. (p. 514)
9, 10—Stichocibicides subcretacea Tappan, n. sp. *9*, Holotype, microspheric, ×53. *10*, Paratype, megalospheric, ×46. *9a, 10b*, Ventral views, *9b, 10a*, dorsal views, *9c, 10c*, edge views. (p. 514)
11–16—Washitella typica Tappan, n. gen., n. sp. *11, 12, 15*, Paratypes, ×35. *13*, Holotype, ×35. *14, 16*, Paratypes, ×53. (p. 515)
17, 18—Washitella triradiata Tappan, n. sp. *17*, Holotype, *18*, paratype, ×53. (p. 515)

ovate, flattened area of small size surrounding the earlier portion of the test. Examples of this type are *Guttulina lactea earlandi* Cushman and Ozawa, *Globulina inaequalis dolfussi* Cushman and Ozawa and *Sigmomorphina concava* (Williamson). In *Globulina dentimarginata* (Chapman) the attached growth is septate, although still only a flattened platelike area.

The specific name refers to the type locality, in the banks of the Red River, Love County, Oklahoma.

Genus PSEUDOPOLYMORPHINA Cushman and Ozawa 1928

PSEUDOPOLYMORPHINA ROANOKENSIS Tappan

Plate 81, figures 4, 5

Pseudopolymorphina roanokensis TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 113, pl. 17, figs. 22a–23, 25.

Test small, elongate, narrow, early portion at first globuline, later becoming uniserial; sutures indistinct; wall calcareous, surface smooth or very finely hispid; aperture invariably obscured by fistulose growth consisting of a number of long, irregular, tapering tubes of various lengths, which are frequently broken. Length of hypotype in figure 4, 0.36 mm., breadth just below fistulose growth 0.08 mm., greatest breadth across fistulose extensions 0.41 mm.; length of hypotype in figure 5, 0.42 mm.

Types.—Hypotypes from locality HTL-13, sample 120.

Remarks.—This species was originally described from the Grayson formation and the range is here extended downward to include the Duck Creek formation.

Subfamily RAMULININAE

Genus RAMULINA Rupert Jones, 1875

RAMULINA ACULEATA Wright

Plate 81, figures 6, 7

Ramulina aculeata WRIGHT, *1886*, Belfast Nat. Field Club Rept. Proc., p. 331, pl. 27, fig. 11.

Ramulina aculeata, BURROWS, SHERBORN and BAILEY, *1890*, Royal Micr. Soc. Jour., p. 561, pl. 11, fig. 16.

Ramulina aculeata, CHAPMAN, *1896*, idem, p. 583, pl. 12, figs. 7–9.

Ramulina aculeata, EICHENBERG, *1933*, Niedersächs geol. Vereins zu Hannover Jahresb. 25, Teil 1, Folge 1, p. 18, pl. 6, figs. 6a, b; *1935*, Roemer-Mus. Mitteil. no. 37, Teil 1, Folge 4, p. 29, pl. 6, fig. 1.

Test free, medium-sized, consisting of globular chambers and branching stoloniferous tubes, globular chambers increasing in size somewhat as added, inflated centrally with distinct and constricted sutures; wall calcareous, surface covered with fine or somwhat larger blunt spines; aperture a rounded opening at the end of the chamber or the open end of the stoloniferous tubes. Length of hypotype of figure 6, 0.77 mm., greatest breadth of largest chamber 0.41 mm.; length of hypotype of figure 7, 1.4 mm., greatest breadth 0.29 mm.

Types.—Hypotype of figure 6 from locality HTL-57, sample 295; hypotype of figure 7 from locality HTL-13, sample 113.

Remarks.—This species occurs in the Gault of England and Germany and is here recorded from the Duck Creek of Texas and Oklahoma. Specimens of both the tubular and globular types have been figured by both Chapman and Eichenberg.

RAMULINA GLOBULIFERA Brady

Plate 81, figures 8, 9

Ramulina globulifera BRADY, *1884*, Rept. Voy. Challenger, Zoology, vol. 9, p. 587, pl. 76, figs. 22–28.

Ramulina globulifera, CHAPMAN, *1896*, Royal Micr. Soc. Jour., p. 582, pl. 12, figs. 5, 6.

Ramulina cf. *globulifera*, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 114, pl. 18, fig. 3.

Test medium-sized, consisting of a subglobular inflated area opening out into numerous tubular projections, which occasionally bifurcate; wall calcareous, surface occasionally very finely hispid; apertures at the open ends of the tubes. Length of hypotype in figure 16, 0.51 mm., greatest thickness 0.14 mm.; length of hypotype in figure 17, 0.57 mm., greatest breadth 0.19 mm.

Types.—Hypotypes from locality HTL-13, sample 113.

Remarks.—This species ranges throughout the Washita group and has been recorded from the Cretaceous to the Recent.

Genus BULLOPORA Quenstedt, 1856

BULLOPORA CERVICORNIS (Chapman)

Plate 81, figure 10

Polymorphina orbignyii var. *cervicornis* CHAPMAN, *1892*, Geol. Mag., n. ser., dec. 3, vol. 9, p. 54, pl. 2, figs. 5, 6.

Ramulina cervicornis, CHAPMAN, *1896*, Royal Micr. Soc. Jour., p. 584, pl. 12, figs. 10, 11.
Vitriwebbina cervicornis, EICHENBERG, *1934*, Niedersächs. geol. Vereins zu Hannover Jahresb. 26, p. 184, pl. 16, fig. 2.
Bullopora cervicornis, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 114, pl. 18, fig. 5.

Test large, an elongate attached tube, much inflated, bifurcating occasionally, with the branching dichotomous; wall calcareous, surface smooth; apertures at the open ends of the tubes. Greatest breadth of hypotype 1.93 mm., greatest breadth of single tube, 0.26 mm.

Type.—Hypotype from locality HTL-34, sample 214.

Remarks.—This species was originally described from England and has been recorded from Germany and from the Grayson formation of Texas. The range is here extended downward to include the Duck Creek formation.

BULLOPORA LAEVIS (Sollas)
Plate 81, figures 11, 12

Vitriwebbina laevis SOLLAS, *1877*, Geol. Mag., n. ser., dec. 2, vol. 4, no. 3, p. 103, pl. 6, figs. 1–3.
Vitriwebbina laevis, CHAPMAN, *1892*, idem, dec. 3, vol. 9, p. 54, pl. 2, fig. 4; *1896*, Royal Micr. Soc., Jour., p. 585, pl. 12, fig. 12.
Bullopora laevis, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 115, pl. 18, fig. 6.

Test medium-sized to large, attached, chambers ovate or rounded in outline, inflated, occasionally possessing a raised central bulb; aperture at the end of a stoloniferous neck. Length of hypotype in figure 11, 0.71 mm., greatest breadth 0.37 mm.; length of hypotype in figure 12, 1.04 mm., breadth 0.72 mm.

Types.—Hypotype of figure 11 from sample 117, hypotype of figure 12 from sample 119, both from locality HTL-13.

Remarks.—This species was originally described from England and has been recorded also from the Grayson formation of Texas. The geologic range is here extended downward to include the Duck Creek formation.

Family HETEROHELICIDAE
Subfamily GÜMBELININAE
Genus GÜMBELITRIA Cushman, 1933
GÜMBELITRIA HARRISI Tappan
Plate 81, figures 13–14b

Gümbelitria harrisi TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 115, pl. 19, figs. 2a–b.

Test minute, triserial, flaring; chambers becoming more inflated and globular as added; sutures distinctly depressed; wall calcareous, surface smooth; aperture low, at the base of the last-formed chamber. Length of hypotype of figure 13, 0.11 mm., breadth 0.10 mm.; length of hypotype of figure 14, 0.17 mm., breadth 0.14 mm.

Types.—Hypotypes from locality HTL-60, sample 300.

Remarks.—This species was originally described from the Grayson formation, and the range is here extended downward to include the Duck Creek formation.

Family BULIMINIDAE
Subfamily BULIMININAE
BULIMINA NANNINA Tappan
Plate 81, figure 15

Bulimina nannina TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 116, pl. 19, figs. 4a, b.

Test tiny, triserial; chambers inflated, earliest chambers very small, increasing rapidly in size, last chamber extending back about one-half the length of the test; sutures distinct, depressed; wall calcareous, surface smooth; aperture loop-shaped, in the face of the last formed chamber. Length of hypotype 0.17 mm., breadth 0.12 mm.

Types.—Hypotype from locality HTL-13, sample 114.

Remarks.—This species was originally described from the Grayson formation, and the range is here extended downward to include the Duck Creek formation.

Genus NEOBULIMINA Cushman and Wickenden, 1928
NEOBULIMINA MINIMA Tappan
Plate 81, figures 16a–b

Neobulimina minima TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 117, pl. 19, figs. 5a–6.

Test very tiny, slender, tapering, nearly circular in cross section, early stage triserial, later biserial, final pair of chambers covering about one-third the length of the test; chambers twisted somewhat about the axis of the test, inflated, slightly elongate; wall calcareous, surface smooth; aperture broad, loop-shaped, at the base of the last-formed chamber. Length of hypotype 0.15 mm., breadth 0.05 mm.

Type.—Hypotype from locality HTL-27, sample 165.

Remarks.—This species was originally described from the Grayson formation and the range is here extended downward to include the Duck Creek formation.

Subfamily VIRGULININAE
Genus VIRGULINA d'Orbigny, 1826
VIRGULINA CRONEISI Tappan, n. sp.
Plate 81, figures 17a–18

Test minute, broad, flattened; chambers biserially arranged and twisted slightly about the center, inflated, elongate and increasing rapidly in size, the last-formed two chambers covering three-fifths or more of the length of the test, the basal margins of the successive chambers being truncate and standing out over the preceding; sutures distinctly depressed, oblique; wall calcareous, surface smooth; aperture loop-shaped, in the face of the last-formed chamber. Length of holotype 0.22 mm., breadth 0.11 mm., greatest thickness 0.08 mm.; length of paratype 0.13 mm., breadth 0.08 mm., thickness 0.04 mm.

Types.—Holotype and paratype from locality HTL-60, sample 303. Paratypes also from the Fort Worth formation.

Remarks.—This species differs from *V. minuta* Cushman in the much more elongate and overhanging chambers, in the fewer chambers and in their truncate bases, which extend out over the preceding ones. The sutures are more oblique and the proloculum elongate rather than rounded. The character of the chambers is somewhat similar to that of *V. marginata* Heron-Allen and Earland, but *V. croneisi* differs in the smaller size, much broader and more flattened test, and the comparatively large later chambers.

VIRGULINA MINUTA Cushman
Plate 81, figures 19, 20

Virgulina minuta CUSHMAN, *1936*, Cushman Lab. Foram. Research Spec. Pub. 6, p. 47, pl. 7, figs. 3a–c; *1937*, idem, Spec. Pub. 9, p. 4, pl. 1, figs. 6, 7.
Virgulina minuta, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 117, pl. 19, figs. 7a, b.

Test tiny, elongate, tapering gradually, base rounded, in the adult the sides becoming subparallel, periphery slightly lobulate, broadly rounded; chambers numerous, increasing gradually in size, inflated; sutures distinct, depressed, oblique; wall calcareous, surface smooth; aperture narrow, elongate, at the inner margin of the last-formed chamber. Length of hypotype of figure 20, 0.23 mm., breadth 0.17 mm., thickness 0.08 mm.

Type.—Hypotypes from locality HTL-27, sample 169.

Remarks.—This species was originally described from the Grayson formation, and the range is here extended downward to include the Duck Creek formation. The species is distinguished by its small size, very gradually enlarging chambers, and very slight degree of twisting.

Subfamily UVIGERININAE
Genus UNICOSIPHONIA Cushman, 1935
UNICOSIPHONIA SUBCRETACEA Tappan, n. sp.
Plate 81, figures 21a–c

Test medium-sized, elongate, narrow, uniserial, straight or slightly arcuate; chambers numerous, increasing slightly in breadth, more rapidly in height, crenulate at the margin with about six backwardly projecting, somewhat overlapping processes, giving a subhexagonal test; sutures distinct, depressed; wall calcareous, finely perforate; aperture rounded, terminal. Length of holotype 1.23 mm., breadth 0.13 mm.

Type.—Holotype from locality HTL-57, sample 295.

Remarks.—This genus has formerly been known only from the Tertiary, and the range is here extended downward to include the Lower Cretaceous. *Unicosiphonia subcretacea* differs from *U. crenulata* Cushman in the more elongate and tapering test, higher chambers and fewer backward projections. The aperture of the holotype of *U. subcretacea* appears elongate, but this is probably due to compression, as the last chamber is somewhat crushed. The type of the genus also had a more distinct neck and an internal tubular structure connecting with the former apertures. Unfortunately many of the Lower Cretaceous specimens of Foraminifera are filled with calcite so that the internal structure is obscured, and it is not possible to determine the presence or absence of this structure in *U. subcretacea* with the material at present available.

Genus DENTALINOPSIS Reuss, 1860

DENTALINOPSIS CHAPPARSI Tappan, n. sp.

Plate 81, figures 26–28b

Test small, elongate, narrow, subtriangular in section; chambers increasing very gradually in breadth from the globular proloculum, increasing more rapidly in height, later ones quite high, sides gently convex, angles rounded, their position best shown by the chambers, which are arched on the sides and curve sharply down the angles of the test; sutures distinct, depressed; wall calcareous, surface smooth; aperture terminal, rounded. Length of holotype 0.455 mm., breadth 0.09 mm.; length of paratype in figure 26, 0.51 mm., breadth 0.09 mm.; length of paratype in figure 27, 0.50 mm., breadth 0.10 mm.

Types.—Holotype and paratype of figure 27 from locality HTL-57, sample 295; paratype of figure 26 from locality HTL-13, sample 114.

Remarks.—This species differs from *Dentalinopsis excavata* (Reuss) in the much narrower test, poorly defined angles, higher chambers and less arched sutures.

DENTALINOPSIS EXCAVATA (Reuss)

Plate 81, figure 22

Rhabdogonium excavatum REUSS, *1862*, Akad. Wiss. Wien. Sitzungsber., Band 46, p. 91, pl. 12, figs. 8a–c.

Dentalinopsis excavata, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 118, pl. 18, figs. 10a, b. Includes additional synonymy.

Test elongate, broad, uniserial, triangular in section, angles subacute; faces nearly flat; chambers numerous, low, increasing gradually in size; sutures distinct but not depressed; wall calcareous, surface smooth; aperture terminal, rounded. Length of hypotype 0.67 mm., breadth 0.28 mm.

Type.—Hypotype from locality HTL-60, sample 303.

Remarks.—This species differs from the typical *D. excavata* (Reuss) in the somewhat larger and comparatively broader test, and in the flat rather than concave faces. *D. excavata* ranges throughout the Washita group.

DENTALINOPSIS MÄRTENSI (Reuss)

Plate 81, figure 23a–b

Rhabdogonium märtensi REUSS, *1863*, Akad. Wiss. Wien Sitzungsber., Band 46, p. 56, pl. 5, fig. 4.

Rhabdogonium maertensi, CHAPMAN, *1894*, Royal Micr. Soc. Jour., p. 160, pl. 4, figs. 10a, b.

Dentalinopsis märtensi, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 119, pl. 18, figs. 11a–c.

Test small, uniserial, narrow, elongate, quadrate in section, angles bluntly rounded; chambers curved downward at the angles, increasing in height as added by expanding very slightly so that the sides of the test are nearly parallel; sutures distinct, very slightly depressed, highly arched in the middle of each side; wall calcareous, surface smooth; aperture terminal, rounded. Length of hypotype 0.43 mm., breadth 0.16 mm.

Type.—Hypotype from locality HTL-13, sample 116.

Remarks.—This species occurs throughout the Washita group but not abundantly.

DENTALINOPSIS NODOSARIA Tappan, n. sp.

Plate 81, figure 24

Test elongate, narrow, medium-sized, subtriangular in section, chambers high, extending downward at the broadly rounded angles, which twist about one-third of the way around the test in a distance of about six chambers, last chamber rounded in section, faces slightly convex; sutures distinct, depressed, arched slightly upward in the center of the faces, downward at the angles of the test; wall calcareous, surface smooth; aperture terminal, rounded. Length of holotype 0.63 mm., breadth 0.15 mm.

Type.—Holotype from locality HTL-34, sample 218.

Remarks.—This species differs from *D. excavata* (Reuss) in the longer and narrower test, higher chambers, and slightly convex rather than excavated faces, and in the less arched sutures and rounded angles.

DENTALINOPSIS QUADRATA Vieaux

Plate 81, figures 25a–b

Dentalinopsis quadrata VIEAUX, *1941*, Jour. Paleontology, vol. 15, no. 6, p. 626, pl. 85, figs. 8a, b.

Test medium-sized, quadrate in section, flaring; chambers increasing gradually in size, sides moderately excavated, angles sharp; sutures distinct, slightly depressed; wall calcareous, surface smooth; aperture

terminal, rounded. Length of holotype 0.78 mm., breadth 0.29 mm., thickness from center of face to center of opposite face 0.22 mm.

Type.—Hypotype from locality HTL-13, sample 121.

Remarks.—This species differs from *D. märtensi* (Reuss) in the larger and broader and slightly flaring test, and more deeply excavated sides and sharp angles.

Dentalinopsis quadrata Vieaux was originally described from the Denton formation, and the range is here extended downward to include the Duck Creek formation.

DENTALINOPSIS TRICARINATUM ACUTANGULUM Reuss
Plate 81, figures 29a–c

Rhabdogonium tricarinatum acutangulum REUSS, *1863*, Akad. Wiss. Wien Sitzungsber., Band 46, p. 55, pl. 4, figs. 14a, b.
Rhabdogonium tricarinatum acutangulum, CHAPMAN, *1894*, Royal Micr. Soc. Jour., p. 159, pl. 4, figs. 8a, b.
Rhabdogonium tricarinatum acutangulum, SCHMITT, *1929*, Zeitsch. f. Geschiebeforschung, Band 5, Heft 3, pl. 5, figs. 15, 15a.
Dentalinopsis tricarinatum acutangulum, TAPPAN, *1940*, Jour. Paleontology, vol. 14, nol 2, p. 119, pl. 18, figs. 13a–c.

Test medium-sized, uniserial, triangular in section, flaring; chambers low and broad, increasing very slightly in height as added, faces of test deeply excavated, angles sharp and acute; sutures distinct, depressed; wall calcareous, surface smooth; aperture terminal, rounded. Length of hypotype 0.54 mm. breadth 0.27 mm., distance from center of one face to tip of opposite angle 0.20 mm.

Type.—Hypotype from locality HTL-13, sample 120.

Remarks.—This species is distinguished by the very deeply excavated faces and regularly flaring test. It ranges throughout the Washita group.

Family SPIRILLINIDAE
Subfamily SPIRILLININAE
Genus SPIRILLINA Ehrenberg, 1843
SPIRILLINA MINIMA Schacko
Plate 82, figures 1a, b

Spirillina minima SCHACKO, *1892*, Foram. u. Ostra. a. d. Kreide von Moltzow, p. 159, pl. 1, fig. 4.
Spirillina minima, FRANKE, *1928*, Preuss. geol. Landesanstalt Abh., n. ser., Band 111, p. 16, pl. 1, fig. 16.
Spirillina minima, TAPPAN. *1940*, Jour. Paleontology, vol. 14, no. 2, p. 119, pl. 19, fig. 8.

Test small, discoidal, planispiral; proloculum comparatively large, globular, second chamber undivided, tubular, closely coiled, with about six volutions in well-developed tests; spiral suture distinct; wall calcareous, surface smooth; aperture formed by the open end of the tube. Greatest diameter of hypotype 0.26 mm., thickness 0.05 mm.

Type.—Hypotype from locality HTL-60, sample 303.

Remarks.—This species was originally described from Germany and has been recorded from the Grayson and Denton formations of this country. The range is here extended downward to include the Duck Creek formation.

Subfamily TURRISPIRILLININAE
Genus TURRISPIRILLINA Cushman, 1927
TURRISPIRILLINA SUBCONICA Tappan, n. sp.
Plate 82, figures 2a–3

Test small, conical, coiled; proloculum small and rounded, followed by an elongate tubular second chamber in a low and hollow conical spire, coils evolute, usually five to six volutions; spiral suture distinct, tubular second chamber nonseptate; wall calcareous, surface smooth; aperture formed by the open end of the tube. Greatest diameter of holotype 0.36 mm., least diameter 0.27 mm., height of spire 0.09 mm.; greatest diameter of paratype 0.25 mm., least diameter 0.21 mm., height of spire 0.05 mm.

Types.—Holotype from locality HTL-34, sample 216; paratype from locality HTL-13, sample 114.

Remarks.—This species differs from *Turrispirillina conoidea* (Paalzow) in the lower spire, the coiling being less involute ventrally, and the test less coarsely perforate. The spire of *T. subconica* is not as distinct in side view as it would appear in section, due to the fairly rapid increase in size of the whorl. The conical appearance is most evident ventrally, due to the deep ventral excavation.

Family ROTALIIDAE
Subfamily DISCORBINAE
Genus PATELLINA Williamson, 1858
PATELLINA SUBCRETACEA Cushman and Alexander
Plate 82, figures 4a, b

Patellina subcretacea CUSHMAN and ALEXANDER, *1930*, Cushman Lab. Foram. Research Contr., vol. 6, p. 10, pl. 3, figs. 1a, b.

Test small, scalelike, in a low spire, ventral side concave, dorsal side slightly convex; early portion consisting of an elongate, spiral undivided tubular chamber of several coils, later chambers narrow and elongate, about two to each whorl; sutures not depressed; wall calcareous, thin, translucent, surface smooth; aperture elongate, at the base of the ventral side of the chamber. Greatest diameter of hypotype 0.26 mm., least diameter 0.25 mm., height of spire 0.08 mm.

Type—Hypotype from locality HTL-34, sample 212.

Remarks.—This species was originally described from the Goodland formation (Fredericksburg group) and has also been recorded in a faunal list from the Denton formation.

Genus DISCORBIS Lamarck, 1804
DISCORBIS MINIMA Vieaux
Plate 82, figures 7a–8b

Discorbis minima VIEAUX, *1941*, Jour. Paleontology, vol. 15, no. 6, p. 627, pl. 85, figs. 10a–c.

Test medium-sized, trochoid, plano-convex, ventral side flattened and umbilicate; chambers increasing rapidly in size, about five to seven chambers in the last volution; sutures distinct, depressed, convex toward the aperture, curving backwards at the periphery; wall calcareous, coarsely perforate; aperture at the base of the umbilical margin of the last-formed chamber on the ventral side. Greatest diameter of hypotype of figure 7, 0.47 mm., least diameter 0.36 mm., greatest thickness 0.21 mm.; greatest diameter of hypotype of figure 8, 0.37 mm., least diameter 0.31 mm., greatest thickness 0.14 mm.

Types.—Hypotypes from locality HTL-13, sample 119.

Remarks.—This species was originally described from the Denton and Fort Worth formations, and the range is here extended downward to include the Duck Creek formation.

DISCORBIS MUNUTISSIMA Tappan, n. sp.
Plate 82, figures 5, 6

Test tiny, planoconvex, trochoid, ventral side flattened, umbilicate; chambers increasing rapidly in size; sutures indistinct, very slightly depressed, oblique and curved dorsally, nearly straight on the ventral side; wall calcareous, finely perforate; aperture at the base of the ventral side of the last-formed chamber. Greatest diameter of holotype 0.16 mm., least diameter 0.13 mm., height 0.08 mm.; greatest diameter of paratype 0.15 mm., height 0.08 mm.

Types.—Holotype and paratype from locality HTL-60, sample 301.

Remarks.—This species differs from *D. minima* Vieaux, in its more minute size and fewer chambers in a volution.

Genus VALVULINERIA Cushman, 1926
VALVULINERIA ASTERIGERINOIDES Plummer
Plate 82, figures 10a–11

Valvulineria asterigerinoides PLUMMER, *1931*, Texas Univ. Bull. 3101, p. 190, pl. 14, fig. 6.
Valvulineria asterigerinoides, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 120, pl. 19, figs. 9a–c.

Test small, trochoid, biconvex, periphery rounded, slightly lobulate; chambers increasing gradually in size, with ventral umbilical flaps overlapping and forming a star-shaped area around the umbilicus, about eight chambers in the last volution; sutures distinct, depressed; slightly curved, convex toward the aperture; aperture near the umbilical area, under a posterior flap of the last chamber. Greatest diameter of hypotype of figure 10, 0.37 mm., least diameter 0.29 mm., greatest thickness 0.13 mm.; greatest diameter of hypotype of figure 11, 0.47 mm., least diameter 0.38 mm., greatest thickness 0.18 mm.

Types.—Hypotypes from locality HTL-13, sample 122.

Remarks.—This species was originally

described from the Grayson formation but ranges throughout the Washita group.

Genus GYROIDINA d'Orbigny, 1826
GYROIDINA LOETTERLEI Tappan
Plate 82, figures 9a–c

Gyroidina loetterlei TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 120, pl. 19, figs. 10a–c.
Gyroidina nitida (Reuss). PLUMMER, *1931*, Texas Univ. Bull. 3101, p. 191, pl. 14, fig. 6.

Test small, trochoid, thick, periphery broadly rounded; chambers increasing gradually in size, last chamber with a broad ventral umbilical flap formed by a posterior extension of the chamber, approximately six chambers in the last volution; sutures distinct, latest ones slightly depressed, nearly straight or very slightly convex toward the aperture, radiating from the center; wall calcareous, surface smooth; aperture a slit at the base of the septal face, extending toward the umbilicus. Greatest diameter of hypotype 0.23 mm., least diameter 0.18 mm., thickness 0.14 mm.

Type.—Hypotype from locality HTL-57, sample 295.

Remarks.—This species ranges abundantly throughout the Washita group.

Subfamily SIPHONININAE
Genus EPISTOMINA Terquem, 1883
EPISTOMINA LENTICULARIA Tappan, n. sp.
Plate 82, figures 12a-c

Test large, trochoid, thinly biconvex, ventrally umbilicate, dorsal side flattened or slightly convex, with a peripheral keel; chambers increasing gradually in size, about eight in the last-formed volution; sutures distinct, slightly curved on the dorsal side, nearly straight ventrally, somewhat thickened; wall calcareous, coarsely perforate; aperture at the inner margin of the ventral side of the last chamber. Greatest diameter of holotype 0.91 mm., least diameter 0.77 mm., thickness 0.22 mm.

Type.—Holotype from locality HTL-34, sample 218.

Remarks.—This species differs from *E. limbata* in the slightly more trochoid character, the depressed, rather than raised sutures, and in lacking the central reticulate area.

EPISTOMINA LIMBATA Tappan, n. sp.
Plate 82, figures 13–14b

Test large, trochoid, biconvex, umbilical area filled; chambers increasing gradually in size, seven to eight in the last volution; sutures distinctly raised and thickened, with early whorls forming a reticulate central area surrounded by highly elevated sutures; wall calcareous; aperture at the inner margin of the ventral side of the chamber. Greatest diameter of holotype 0.55 mm., least diameter 0.38 mm., thickness 0.16 mm.; greatest diameter of paratype 0.87 mm., least diameter 0.83 mm., thickness 0.25 mm.

Types.—Holotype from locality HTL-13, sample 116, paratype from locality HTL-34, sample 218.

Remarks.—This species differs from *E. spinulosa* Reuss in the straighter sutures and somewhat smaller size but is similar in the highly elevated sutures and reticulate central area.

Family GLOBIGERINIDAE
Genus GLOBIGERINA d'Orbigny, 1826
GLOBIGERINA CRETACEA d'Orbigny
Plate 82, figures 16a–17

Globigerina cretacea D'ORBIGNY, *1840*, Soc. géol. France Mém., sér. 1, t. 4, p. 34, pl. 3, figs. 12–14.
Globigerina cretacea, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 121, pl. 19, figs. 11a–c. Includes additional synonymy.

Test medium-sized, trochoid, periphery broadly rounded; chambers much inflated, globular, four to five in the last volution; sutures distinct, deeply depressed, nearly straight; wall calcareous, surface smooth or very finely hispid; aperture extending from the periphery into the umbilical area. Greatest diameter of hypotype in figure 16 0.35 mm., least diameter 0.31 mm., thickness through last chamber 0.21 mm.; greatest diameter of hypotype of figure 17, 0.20 mm., least diameter 0.14 mm., thickness through last chamber 0.11 mm.

Types.—Hypotypes from locality HTL-13, sample 119.

Remarks.—This species occurs abundantly throughout the Washita group, and has been recorded widely from strata varying in age from Cretaceous to Recent.

GLOBIGERINA GRAYSONENSIS Tappan
Plate 82, figures 15a–c

Globigerina graysonensis TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 122, pl. 19, figs. 15–17.

Test tiny, trochoid, dorsal side varying from slightly convex to a distinct spire, periphery broadly rounded; chambers increasing rapidly in size, inflated, globular, three to five in the last volution; sutures distinct, depressed, slightly curved backwards at the periphery; wall calcareous, surface smooth; aperture slitlike, at the lower margin of the last chamber, ventral in position. Greatest diameter of hypotype 0.13 mm., least diameter 0.12 mm., thickness 0.09 mm.

Type.—Hypotype from locality HTL-60, sample 301.

Remarks.—This species was originally described from the Grayson formation, and the range is here extended downward to include the Duck Creek formation. The species is more common in the upper part of the Washita, however.

GLOBIGERINA PLANISPIRA Tappan
Plate 83, figure 3

Globigerina planispira TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 122, pl. 19, figs. 12a–c.

Test medium-sized to small, flattened, trochoid, about 2½ volutions visible from the dorsal side; chambers numerous, increasing in size as added, globular, much inflated; sutures distinctly depressed, constricted; wall calcareous, surface smooth; aperture at the base of the ventral side of the last formed chamber. Greatest diameter of hypotype 0.44 mm., least diameter 0.33 mm., greatest thickness 0.22 mm., thickness through last chamber 0.20 mm.

Type.—Hypotype from locality HTL-13, sample 112.

Remarks.—This species ranges throughout the Washita group, the specimens of the lower part of the Washita group being larger and better developed.

GLOBIGERINA WASHITENSIS Carsey
Plate 83, figures 1a–2

Globigerina washitensis CARSEY, *1926*, Texas Univ. Bull. 2612, p. 44, pl. 7, fig. 10, pl. 8, fig. 2.

Globigerina washitensis, TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 122, pl. 19, figs. 13a–c. Includes additional synonymy.

Test large, trochoid, bulbous; chambers inflated, increasing rapidly in size, four to six in the last volution, early chambers forming a low trochoid spire; sutures distinctly depressed; wall calcareous, surface covered with coarse reticulations forming a honeycomb pattern; aperture at the base of the last-formed chamber, opening into a deep umbilical excavation. Greatest diameter of hypotype in figure 1, 0.47 mm., least diameter 0.43 mm., greatest thickness 0.29 mm.; greatest diameter of specimen in figure 2, 0.59 mm., least diameter 0.49 mm., greatest thickness 0.37 mm.

Types.—Hypotypes from locality HTL-57, sample 294.

Remarks.—This species occurs throughout the Washita group, specimens from the lower part being larger and more abundant.

Genus GLOBIGERINELLA Cushman, 1927

GLOBIGERINELLA CUSHMANI Tappan, n. sp.
Plate 83, figures 5a, b

Test small, planispiral, involute, biumbilicate; chambers increasing rapidly in size, later ones much inflated, about eight in the last volution; sutures distinctly depressed; wall calcareous, surface finely perforate; aperture an arch at the base of the last-formed chamber, on the periphery. Greatest diameter of holotype 0.30 mm., least diameter 0.25 mm., greatest thickness 0.25 mm., least thickness 0.08 mm.

Type.—Holotype from locality HTL-13, sample 120.

Remarks.—This species differs from *Globigerinella aequilateralis* (Brady) in the much smaller size, greater number of chambers per volution, more involute coiling, deep umbilicus, and smooth or pitted rather than spinose surface.

Genus HASTIGERINELLA Cushman, 1927

HASTIGERINELLA SUBCRETACEA Tappan, n. sp.
Plate 83, figures 4a–c

Test small, slightly trochoid, flattened, periphery broadly rounded; chambers numerous, increasing rapidly in size, six to

seven in the last-formed volution, the later chambers much inflated and radially elongated; sutures distinctly depressed; wall calcareous, surface very finely perforate; aperture an arch at the base of the last-formed chamber and slightly ventrally placed on the periphery. Greatest diameter of holotype 0.42 mm., least diameter 0.27 mm., thickness 0.10 mm.

Type.—Holotype from locality HTL-13, sample 120.

Remarks.—This species differs from *H. eocenica* Nuttall in the smaller size, narrower and more numerous chambers, and the more trochoid appearance. It is similar in the comparatively short chambers, for this genus, and in the even size throughout.

Hastigerinella subcretacea is a very primitive species of the genus, and shows many of the characters of *Globigerina* and *Globigerinella*, suggesting the possible origin of the genus *Hastigerinella*.

The genus *Hastigerinella* was formerly known only from the Upper Cretaceous to the Recent, and the generic range is here extended downward into the Lower Cretaceous.

Family ANOMALINIDAE
Subfamily ANOMALININAE
ANOMALINA PLUMMERAE Tappan
Plate 83, figures 6–8c

Anomalina plummerae TAPPAN, *1940*, Jour. Paleontology, vol. 14, no. 2, p. 124, pl. 18, figs. 15a–16.
Anomalina petita CARSEY, *1926* (nom. nudum), Texas Univ. Bull. 2612, p. 48 (but not pl. 7, fig. 31, as a cristellarian test was erroneously figured in place of this species).
Anomalina falcata (Reuss). PLUMMER, *1931*, Texas Univ. Bull. 3101, p. 202, pl. 14, figs. 7–8.

Test medium-sized, trochoid, compressed, biconvex, periphery subacute; chambers numerous, increasing gradually in size, 9 to 11 occurring in the last volution, center of the dorsal side covered by a conspicuous boss, obscuring the earliest whorls; sutures distinct, depressed, bending backward at the periphery; aperture a low arch over the periphery, extending somewhat ventrally. Greatest diameter of hypotype of fig. 6, 0.28 mm., least diameter 0.22 mm., thickness through center 0.11 mm.; diameter through last chamber of hypotype of figure 7, 0.64 mm., diameter perpendicular to the preceding, 0.54 mm., thickness through last chamber 0.24 mm.; greatest diameter of hypotype of figure 8, 0.69 mm., least diameter 0.53 mm., thickness through last chamber 0.21 mm.

Types.—Hypotypes all from locality HTL-57, sample 296.

Remarks.—This species ranges abundantly throughout the Washita group. A number of freakish specimens occur, some twinned, and an example is shown in figure 7 of a specimen in which the coiling began in one plane and later chambers added in another, giving a test which appears bent through the center.

Subfamily CIBICIDINAE
Genus STICHOCIBICIDES Cushman and Bermudez, 1936
STICHOCIBICIDES SUBCRETACEA Tappan, n. sp.
Plate 83, figures 9a–10c

Test medium in size, compressed, attached dorsally, ventrally umbilicate, trochoid in early stage, later becoming uniserial, periphery rounded, narrow; chambers numerous, about 10 in the last whorl of the microspheric form, only 6 in the last megalospheric whorl, about 2½ whorls visible dorsally, chambers increasing gradually in size; sutures slightly depressed on the ventral side, strongly curved; wall calcareous, coarsely perforate on the outer side; aperture on the ventral side of the last-formed chamber, near the periphery. Length of holotype 0.53 mm., least diameter of coil 0.40 mm., greatest thickness 0.10 mm.; length of paratype 0.54 mm., breadth of coil 0.29 mm., thickness of coil 0.11 mm., breadth of uniserial portion 0.27 mm., thickness of uniserial portion 0.06 mm.

Type.—Holotype from locality HTL-27, sample 167; paratype from locality HTL-60, sample 301.

Remarks.—The genus *Stichocibicides* has been known only from the Eocene, and the range is here extended downward into the Lower Cretaceous. *Stichocibicides subcretacea* differs from *S. cubensis* Cushman and Bermudez in the comparatively larger coiled portion, greater number of chambers per whorl of the coiled portion, ventral umbilicus, and shorter uniserial stage.

Family unknown
Genus WASHITELLA Tappan, n. gen.

Genotype, *Washitella typica* Tappan, n. sp.

Test free, consisting of well-defined but very irregularly arranged chambers; may be in a linear or slightly coiled series or branch in various ways; wall calcareous, finely perforate; apertures at the end of the series of chambers, occasionally more than one.

WASHITELLA TYPICA Tappan, n. sp.
Plate 63, figures 11–16

Genus? species? TAPPAN, *1940*, Jour. Paleontology vol. 14, no. 2, p. 124, pl. 18, figs. 17a–18b.

Test medium-sized to small, irregular in growth, periphery rounded; chambers numerous, usually with two to four comparatively large chambers in the central portion of the test, arranged in either a linear or somewhat coiled series, with smaller chambers branching from these in various directions but usually with a series of three or four of the smaller chambers extending along one main axis, with shorter series extending laterally, chambers inflated, varying from globular to flattened, from low and broad to elongate and narrow; sutures distinct, depressed; wall calcareous, finely perforate, surface smooth; apertures at the ends of the smaller chambers. Length of holotype 0.55 mm.; length of paratype in figure 11, 0.69 mm.; length of paratype in figure 12, 0.28 mm.; length of paratype in figure 14, 0.55 mm., greatest breadth 0.27 mm.; length of paratype in figure 15, 0.66 mm.; length of paratype in figure 16, 0.41 mm., greatest breadth 0.18 mm.

Types.—Holotype and paratypes of figures 11, 14 and 16 from locality HTL-13, sample 119; paratypes of figures 12 and 15 from locality HTL-57, sample 294.

Remarks.—Tappan (1940) in discussing the occurrence of this species in the Grayson formation, stated that

> This form apparently does not fit any of the genera thus far described and its position is extremely doubtful. Some specimens resemble the genus *Schackoina*. . . . The Recent forms *Calcituba polymorpha* Roboz and *Sporadogenerina flintii* Cushman have a somewhat similar irregular appearance and the Grayson form may later be found to belong to one of these genera.

After studying a great many specimens from this and other horizons in the Washita, it is believed that the species represents a new genus, which is here described as *Washitella*. Although a few of the tiny forms seem surficially to resemble *Schackoina*, larger and better-developed ones show a linear arrangement of chambers entirely unlike that genus. *Calcituba* is an attached genus with an imperforate calcareous wall, while the present species is free-living and has a finely perforate wall. *Sporadogenerina* has an early Uvigerine stage, lacking in the present species, and although the later chambers of *Sporadogenerina* are irregularly uniserial, they do not show the branching and growth in various directions from the larger central chambers.

WASHITELLA TRIRADIATA Tappan, n. sp.
Plate 83, figures 17, 18.

Test medium-sized to small; composed of numerous chambers, arranged in a triaxial linear series and of approximately the same size throughout the length of the test, chambers somewhat rounded in section, of approximately equal length and breadth, probably growth was at first rectilinear, then bifurcation occurred to form the three axes; sutures distinct, depressed; wall calcareous, finely perforate; apertures at the ends of the series of chambers. Length of holotype 0.45 mm., diameter just before bifurcation 0.11 mm.; length of paratype 0.16 mm., diameter of last chamber 0.06 mm.

Types.—Holotype and paratype from locality HTL-13, sample 114.

Remarks.—This species is more similar to *Ramulina* than the preceding as growth is more regular. *Ramulina* in typical development consists of rounded chambers connected by long stoloniferous tubes or of tubular branching unchambered tests, while the present species has closely appressed and well-developed chambers. *W. triradiata*, n. sp. differs from *W. typica*, n. sp. in the tri-axial growth and equal-sized chambers.

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ADDITIONS TO THE FAUNA OF THE TRENT MARL OF NORTH CAROLINA

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ABSTRACT—The marine invertebrate fauna of the Trent formation of North Carolina is reviewed in the light of recent collections made from the vicinity of Silverdale, North Carolina. Thirty-one additional fossils including 11 new species or varieties are recorded, bringing to 54 the total fauna of the formation. The present study tends to confirm the Lower Miocene dating of the formation.

THE Trent marl of North Carolina was originally regarded as Eocene (Miller 1912); however, a restudy of the formation including an analysis of its invertebrate fauna by Kellum (1926) demonstrated that it was younger, probably of lower Miocene age, although there was a possibility that it might be Oligocene. The present paper records 31 additional fossils including 11 new species or varieties obtained from the Trent in the vicinity of Silverdale, Onslow County, North Carolina. This brings to 54 the total fauna from the Trent. The additions tend to confirm the lower Miocene age of the formation.

At most localities the Trent consists of consolidated limestone with only indistinct casts of fossils. However, at two localities excellent unaltered fossils have been obtained.

1. Gillette marl pits, on the left side of Webbs Creek, half a mile southeast of Silverdale, Onslow County, N. C. This is the locality where Kellum obtained the large collection of fossils upon which he based his determination of the age of the formation. Recent excavations had apparently dug a little deeper with the result that additional material was available.

2. Askew marl pits, 2 miles northwest of Silverdale, Onslow County, N. C. Here the Trent marl is overlain by the Croatan sand (Pliocene). In the stream bed the fossils are definitely from the Trent, while in the higher levels of the pit the fossils are definitely from the Croatan. However, much of the intermediate material is mixed, the mixture probably having taken place during the Pliocene at the time of the deposition of the Croatan sand. Therefore, only material definitely from the lower layer is included in this report.

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SPECIES FROM SILVERDALE AND VICINITY

The species listed in this paper have been reported from the vicinity of Silverdale, chiefly from the Gillette and Askew pits. For complete bibliography and notes on the species reported by Kellum, see his paper (1926). The present paper includes

illustrations of all new species and varieties as well as those reported for the first time from the Trent formation. In addition, illustrations are provided of all species listed by Kellum but not figured by him. Therefore, by the use of this paper together with the original report by Kellum, the reader may obtain all available data on the Trent fauna, including an illustration of every species.

One set of fossils, including types and figured specimens, is at the Academy of Natural Sciences of Philadelphia. An additional set, including paratypes, is at the North Carolona State Museum in Raleigh, N. C.

ARCA SILVERDALENSIS Kellum

Arca silverdalensis KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 34, pl. 8, figs. 1–3.

Gillette, common; Askew, fairly common. Trent only.

GLYCYMERIS ANTEPARILIS Kellum

Glycymeris anteparilis KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 35, pl. 8, figs. 4–6.

Gillette, fairly common, mostly broken shells. Trent only. Close to *G. parilis* Conrad from Miocene of New Jersey and Maryland.

PECTEN TRENTENSIS Harris
Plate 84, figures 12, 25

Pecten trentensis HARRIS, *1919*, Bull. Am. Paleontology, vol. 8, no. 33, p. 15, pl. 2, figs. 8, 9.
Pecten trentensis, KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 35.

Reported by Harris from the right bank of the Trent river, 6 miles below Pollocksville, N. C. Trent only.

PECTEN ELIXATUS Conrad?
Plate 84, figures 9, 22

Pecten elixatus CONRAD, *1846*, Acad. Nat. Sci. Philadelphia Proc., vol. 2, p. 174.
Pecten elixatus?, HARRIS, *1919*, Bull. Am. Paleontology, vol. 8, no. 33, p. 15, pl. 2, figs. 10, 11.
Pecten elixatus?, KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 35.

Shells questionably referred to this species were reported by Harris from 6 miles below Pollocksville, N. C., associated with *P. trentensis*. Eocene; South Carolina (Santee); Miocene: North Carolina (Trent?).

PLICATULA DENSATA Conrad
Plate 84, figures 5, 6

Plicatula densata CONRAD, *1843*, Acad. Nat. Sci. Philadelphia Proc., vol. 1, p. 311.
Plicatula densata, KELLUM, *1926*. U. S. Geol. Survey Prof. Paper 143, p. 36.

Gillette, common; Askew, fairly common. Miocene: New Jersey (Kirkwood); Maryland (Calvert); Virginia (Yorktown); North Carolina (Trent, Yorktown); Florida (Tampa, Alum Bluff).

OSTREA GEORGIANA Conrad, var.?
Plate 86, figures 1–3

Ostrea georgiana CONRAD, *1834*, Acad. Nat. Sci. Philadelphia Jour., vol. 7, p. 156.

Numerous broken pieces and a few perfect specimens of oyster shells were found in the Gillette marl pits. Although none were sufficiently perfect to permit positive identification, a few valves were found to closely resemble young specimens of *O. georgiana* in the collections of the Academy.

One very large and thick shell (8½ inches long; 6 inches wide and 5 inches thick) was obtained by Mr. Gillette from these pits several years ago (figs. 1, 3). This also bears a resemblance to *O. georgiana*, but is much more rounded than any specimen of *O. georgiana* observed.

O. georgiana is known from the Castle Hayne marl (Eocene) at Pollocksville, N. C. only about 20 miles from Silverdale. The Castle Hayne underlies the Trent, and it is entirely possible that the excavations penetrated through the Trent into the Eocene. However, this does not seem likely in view of the lack of other Eocene species. It is more probable that these shells represent the lower Miocene descendent of the Eocene *O. georgiana*.

MYTILUS CONRADINUS d'Orbigny
Plate 84, figure 17

Mytilus conradinus D'ORBIGNY, *1852*, Prodr. Pal., vol. 3, p. 127.

Gillette, one broken shell. Miocene: Maryland (Calvert, Choptank); North Carolina (Duplin); South Carolina.

ANOMIA ONSLOWENSIS Richards, n. sp.
Plate 84, figures 10, 11.

Shell of moderate size, thin, roughly circular in outline, umbones distinct. Surface covered with radial lineation similar to but coarser than *A. glypta* Gardner. The type specimen shows 10 primary ribs separated from each other by fairly smooth interspaces. Muscle scar elongate dorsal-ventrally. Hinge edentulous.

Length of type (ANSP 15804), 31 mm.; width, 37 mm.

Width of paratype (NCSM), 30 mm.

Type locality, Gillette marl pits, Silverdale, Onslow Co., N. C. Very close to *A. glypta* Gardner from the Chipola formation (Alum Bluff group) of Florida. Distinguished by its fewer and coarser ribs. Two imperfect specimens are all that have been obtained.

ASTARTE ONSLOWENSIS Kellum

Astarte onslowensis KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 36, pl. 8, figs. 8–10.

Gillette, very rare; Askew, a few shells questionably referred to this species. Trent only.

CRASSATELLITES MISSISSIPPIENSIS SILVERDALENESIS Kellum

Crassatellites mississippiensis silverdalensis KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 36, pl. 8, figs. 11, 12.

Gillette, broken shells fairly common; Askew, a few broken shells. Trent only. *C. mississipiensis* is from the Vicksburg (Oligocene) of Mississippi.

VENERICARDIA NODIFERA Kellum

Venericardia nodifera KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 36, pl. 9, figs. 1–3.

Gillette, fairly common. Trent only.

VENERICARDIA GRANULATA Say
Plate 84, figures 18, 19

Venericardia granulata SAY, *1824*, Acad. Nat. Sci. Philadelphia Jour., vol. 4, p. 142, pl. 12, fig. 1.

Venericardia granulata, KELLUM, U. S. Geol. Survey Prof. Paper 143, p. 37.

Gillette, fairly common; Askew, common. Miocene: New Jersey (Kirkwood); Maryland (Calvert, Choptank, St. Mary's); Virginia (Yorktown); North Carolina (Trent, Yorktown, Duplin); South Carolina; Florida. Pliocene: North Carolina (Croatan, Waccamaw), South Carolina (Waccamaw).

DIPLODONTA ALTA Dall?
Plate 84, figures 20, 21

Diplodonta alta DALL, *1890*, Wagner Free Inst. Sci. Trans., vol. 3, pt. 1, p. 189, pl. 11, figs. 9a, b.

Gillette, a young shell questionably referred to this species. Miocene: Florida (Tampa).

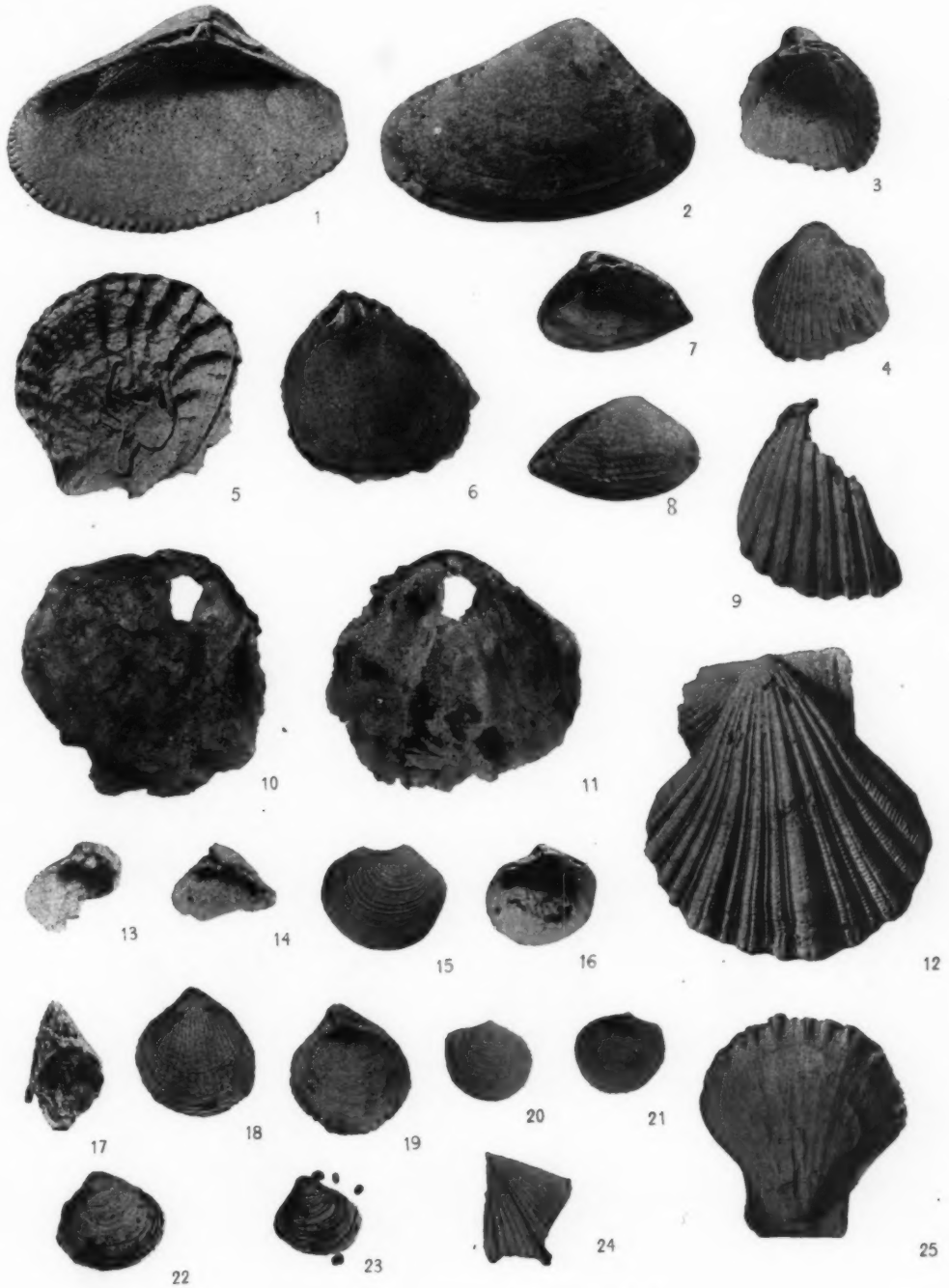
PHACOIDES NOCARIENSIS Kellum

Phacoides nocariensis KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 37, pl. 9, figs. 4, 5.

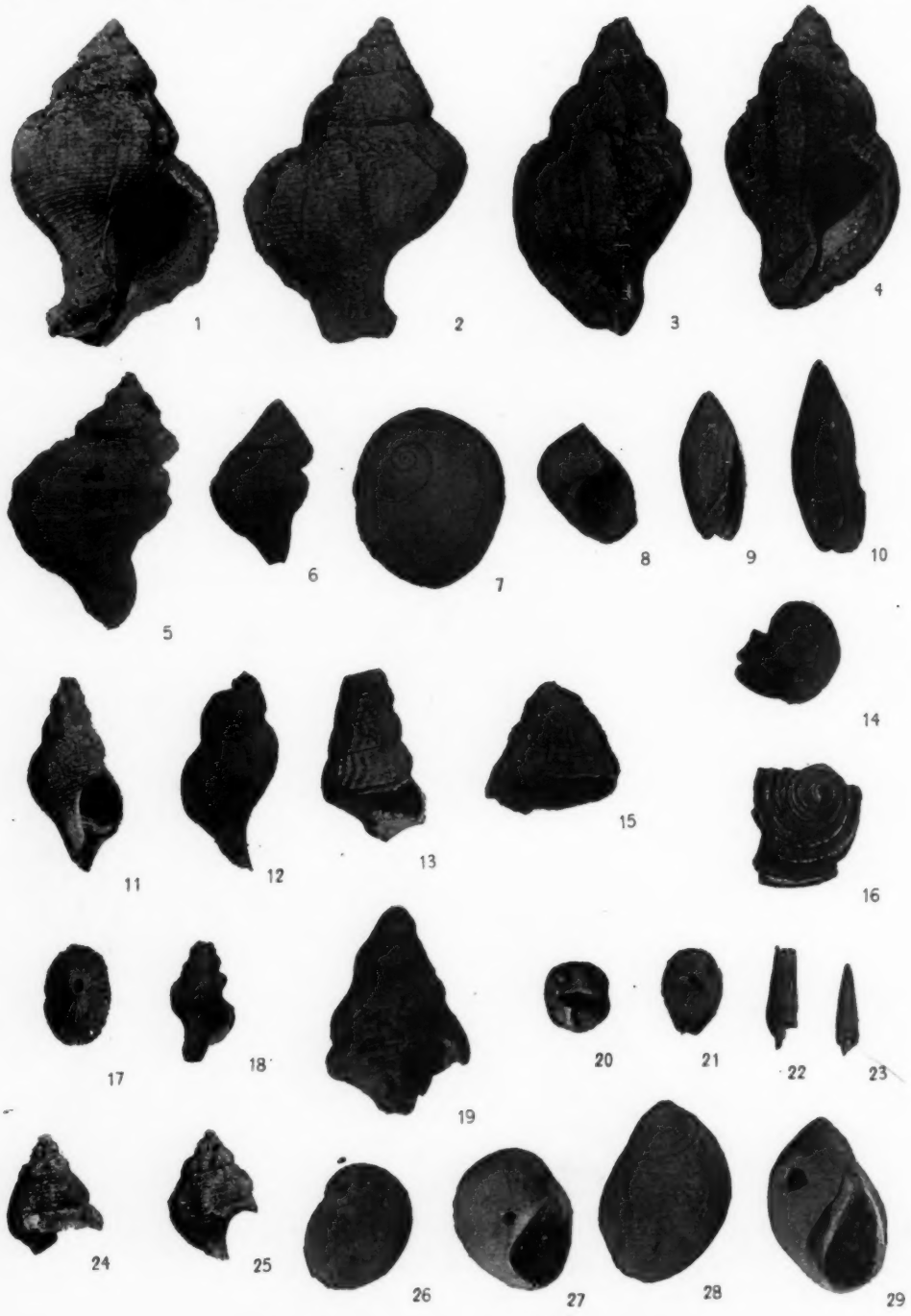
EXPLANATION OF PLATE 84

Figures *9*, *12*, *22*, and *25* from 6 miles below Pollocksville, N. C.; all others from Gillette marl pits, Silverdale, N. C.

FIGS. *1*, *2*—*Donax idoneus* Conrad. ANSP 15817, ×1. (p. 522)
3, *4*—*Cardium midyetti* Richards, n. sp. Holotype, ANSP 15820, ×1. (p. 521)
5, *6*—*Plicatula densata* Conrad. ANSP 15822, ×1. (p. 519)
7, *8*—*Corbula burnsi* Dall. ANSP 15823, ×3. (p. 522)
9—*Pecten elixatus* Conrad?. Pal. Res. Inst. (p. 519)
10, *11*—*Anomia onslowensis* Richards, n. sp. Holotype, ANSP 15804, ×1. (p. 520)
12—*Pecten trentensis* Harris, Holotype, Pal. Res. Inst., ×1. (p. 519)
13, *14*—*Corbula idonea* Conrad. ANSP 15821, ×1. (p. 522)
15, *16*—*Phacoides silicatus* Mansfield. ANSP 15824, ×3. (p. 521)
17—*Mytilus conradinus* d'Orbigny. ANSP 15819, ×1. (p. 519)
18, *19*—*Venericardia granulata* Say. ANSP 15808, ×1. (p. 520)
20, *21*—*Diplodonta alta* Dall?. ANSP 15825, ×1. (p. 520)
22—*Pecten elixatus* Conrad?. Pal. Res. Inst., ×1. (p. 519)
23—*Gemma magna* Dall. ANSP 15810, ×4. (p. 522)
24—*Gemma magna striata* Richards, n. var. Holotype, ANSP 15810, ×4. (p. 522)
25—*Pecten trentensis* Harris. Pal. Res. Inst., ×1. (p. 519)



Richards, Miocene (Trent) Mollusca



Richards, Miocene (Trent) Mollusca

Gillette, reported by Kellum but not found on present survey. Trent only.

PHACOIDES SILICATUS Mansfield
Plate 84, figures 15, 16

Phacoides silicatus MANSFIELD, *1937*, Florida Geol. Survey Bull. p. 242, pl. 17, figs. 4, 5, 6, 8. (For other references see Mansfield.)

Gillette, rare. Miocene: North Carolina (Trent); Florida (Tampa.)

CARDIUM MIDYETTI Richards, n. sp.
Plate 84, figures 3, 4.

Shell thin, polished, with large full beaks; subequilateral, rounded in front and below. Thirteen smooth ribs at center of shell. Both anterior and posterior areas are smooth with only faint traces of ribs. Faint cross striations on the posterior side only. Hinge typical of the genus.

Length of type (ANSP 15820), 21 mm.; width, 19 mm. Length of paratype (broken) (NCSM); width, 20 mm.

Type locality, Gillette marl pits, Silverdale, N. C.

Related to *Cardium* (*Cerastoderma*) *chipolanum* Dall from the Chipola formation (Alum Bluff group) of Florida. Distinguished by its fewer and smoother ribs and by the smooth areas on both anterior and posterior edges of the shell.

Named in honor of Mr. Allen L. Midyette who was field assistant during the recent survey.

MACROCALLISTA TIA Kellum

Macrocallista tia KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 38, pl. 10, figs. 1, 2.

Gillette, common; Askew, rare. Trent only.

CALLISTA NEUSENSIS (Harris)

Meretrix neusensis HARRIS, *1919*, Bull. Am. Paleontology, vol. 6, no. 31, p. 136, pl. 43, figs. 4–7, 10.
Macrocallista minuscula KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 38, pl. 10, figs. 1, 2.
Callista neusensis, PALMER, *1927*, Paleontographica Americana, vol. 1, no. 5, p. 281.
Callista neusensis, KELLUM, *1931*, Washington Acad. Sci. Jour., vol. 21, p. 51.

Described by Harris from the Trent formation at Rock Landing on the Neuse River.

Gillette, very common; Askew, a few young shells.

ANTIGONA LAMELLACEA Kellum

Antigona (*Artena*) *lamellacea* KELLUM, *1926*, U.S. Geol. Survey Prof. Paper 143, p. 38, pl. 9, figs. 13, 14.

Gillette, very rare; Askew, rare. Trent only.

EXPLANATION OF PLATE 85

All specimens from Gillette marl pits, Silverdale, N. C.

FIGS. *1, 2—Murex davisi* Richards, n. sp. Holotype, ANSP 15836, ×1. (p. 524)
3, 4—Murex kellumi Richards, n. sp. Holotype, ANSP 15838, ×1. (p. 524)
5—Rapana gilletti Richards, n. sp. Holotype, ANSP 15840, ×1. (p. 524)
6—Rapana vaughani Mansfield. ANSP 15839, ×1. (p. 524)
7—Polinices duplicata (Say). ANSP 15826, ×1. (p. 522)
8—Sinum imperforatum Dall. ANSP 15830, ×1. (p. 523)
9—Oliva posti Dall. ANSP 15835, ×1. (p. 525)
10—Olivella gardnerae Richards, n. sp. Holotype, ANSP 15832, ×4. (p. 525)
11, 12—Fusinus trentensis Richards, n. sp. *11*, Holotype, ANSP 15856, ×1. *12*, Paratype, NCSM, ×1. (p. 525)
13—Potamides silverdalensis Richards, n. sp. Holotype, ANSP 15846, ×1. (p. 523)
14—Leiostrichus sp. ANSP 15843, ×3½. (p. 526)
15—Crucibulum constrictum (Conrad). ANSP 15849, ×1. (p. 523)
16—Ecphora quadricostata (Say), ANSP 15853, ×2. (p. 524)
17—Diadora chipolana caroliniana Richards, n. var. Holotype, ANSP 15834, ×2. (p. 522)
18—Eupleura harbisoni Richards, n. sp. Holotype, ANSP 15852, ×1. (p. 523)
19—Siphonalia migrans (Conrad). ANSP 15854, ×1. (p. 525)
20—Crepidula fornicata (Linné). ANSP 15851, ×2. (p. 523)
21—Crepidula plana Say. ANSP 15850, ×1. (p. 523)
22, 23—Terebra whitfieldi Martin *22*, ANSP 15855, ×1. *23*, NCSM, ×1. (p. 526)
24, 25—Coralliophila cumberlandia (Gabb). ANSP 15847. ×1. (p. 524)
26, 27—Polinices judsoni (Maury)?. ANSP 15828, ×3½. (p. 523)
28, 29—Polinices hemicrypta (Gabb). ANSP 15829, ×3½. (p. 523)

VENUS GARDNERAE Kellum

Venus gardnerae KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 37, pl. 9, figs. 8, 9.

Gillette, very common. Trent only.

VENUS ERECTA Kellum

Venus erecta KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 38, pl. 9, figs. 10–12.

Gillette, common; Askew, rare. Trent only.

GEMMA MAGNA Dall
Plate 84, figure 23

Gemma magna DALL, *1903*, Wagner Free Inst. Sci. Trans., vol. 3, pt. 6, p. 1330, pl. 57, fig. 4.

Gillette, rare. Miocene: North Carolona (Trent, Duplin). Pliocene: South Carolina (Waccamaw); Florida (Caloosahatchee). Pleistocene: Florida (Pamlico).

GEMMA MAGNA STRIATA Richards n. var.
Plate 84, figure 24

Similar to the typical *G. magna* Dall but with prominent concentric striations. Found with the typical species at the Gillette marl pits, Silverdale, N. C.

Length of type (ANSP 15810), 3.0 mm.; width, 3.5 mm.

Type locality, Gillette marl pits, Silverdale, N. C.

DONAX IDONEUS Conrad
Plate 84, figures 1, 2

Donax idoneus CONRAD, *1872*, Acad. Nat. Sci. Philadelphia Proc., vol. 24, p. 216, pl. 7, fig. 2.

Shell large and thick for the genus; ellipsoidal, smooth, with faint traces of radial striation. Anterior end obliquely truncate, with a slightly flattened "shelf" at the margin. Hinge about two-thirds of the way toward the anterior end of the shell and characteristic of the genus. Conspicuous crenulations along the inner margin of the shell.

Length of figured specimen (ASNP 15817) 28.0 mm.; width, 43.0 mm.

Gillette marl pits, Silverdale, N. C.

These shells are apparently identical with *Donax idoneus* described by Conrad from the "Coast of North Carolina, probably from a Miocene bed under the sea." Although it is difficult to recognize the species from Conrad's description, his figures are identical with the specimens recently collected.

The species is unrelated to any other known East Coast *Donax*, but apparently is very close to *D. punctostriatus* Hanley from the Recent of Lower California and the west coast of Mexico south to Peru. The Miocene species differs mainly in being less truncate, having more prominent teeth and a somewhat less conspicuous flat shelf on the anterior margin.

The close relationship of *D. idoneus* from the lower Miocene of North Carolina and *D. punctostriatus* from the Recent Pacific of Lower California, etc., adds further evidence to the theory of a Tertiary sea across Mexico, probably at the Isthmus of Tehauntepec.

CORBULA BURNSI Dall
Plate 84, figures 7, 8

Corbula elongata var. *burnsi* DALL, *1898*, Wagner Free Inst. Sci. Trans., vol. 3, pt. 4, p. 847.
Corbula burnsi, DALL, *1937*, Florida Geol. Survey Bull. 15, p. 279.

Gillette, fairly common. Miocene: North Carolina (Trent); Florida (Tampa, Alum Bluff).

CORBULA IDONEA Conrad
Plate 84, figures 13, 14

Corbula idonea CONRAD, *1833*, Am. Jour. Sci., vol. 23, p. 341.

Gillette, rare, broken shells. Miocene: New Jersey (Kirkwood); Maryland (Calvert, Choptank); North Carolina (Trent).

DIADORA CHIPOLANA CAROLINIANA
Richards, n. var.
Plate 85, figure 17

One young shell similar to *D. chipolana* Dall from the Alum Bluff group of Florida but with the ribs somewhat closer together.

Length of type (ANSP 15834), 4.5 mm.; width, 3.0 mm.

Type locality, Gillette marl pits, Silverdale, N. C.

POLINICES DUPLICATA (Say)
Plate 85, figure 7

Natica duplicata SAY, *1822*, Acad. Nat. Sci. Philadelphia Jour., vol. 2, p. 247.

Gillette, common; Askew, common. Miocene: New Jersey (Kirkwood); Maryland

(Calvert, Choptank, St. Mary's); Virginia; North Carolina (Trent, Yorktown); Florida.

POLINICES HEMICRYPTA (Gabb)
Plate 85, figures 28, 29

Natica hemicrypta GABB, *1860*, Acad. Nat. Sci. Philadelphia Jour., ser. 2, vol. 4, p. 375, pl. 67, fig. 5.

Gillette, fairly common young specimens. Miocene: New Jersey (Kirkwood); Maryland (Calvert, Choptank); North Carolina (Trent); Florida (Tampa).

POLINICES JUDSONI (Maury)
Plate 85, figures 26, 27

Natica judsoni MAURY, *1910*, Bull. Am. Paleontology, vol. 4, no. 21, p. 29, pl. 7, fig. 6.

A few specimens from the Gillette pits are questionably referred to this species Florida (Alum Bluff); North Carolina (Trent?).

SINUM IMPERFORATUM Dall
Plate 85, figure 8

Sinum imperforatum DALL, *1915*, U. S. Nat. Mus. Bull. 90, p. 109, pl. 5, fig. 8.
Sinum imperforatum, KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 40.

Gillette, fairly common; Askew, common. Miocene: North Carolina (Trent); Florida (Tampa).

CALYPTRAEA TROCHIFORMIS Lamarck
Plate 86, figures 6, 7

Calyptraea trochiformis LAMARCK, *1804*, Annals du Museum, Paris, vol. 5, pt. 1, p. 385, pl. 15, fig. 3.
Calyptraea trochiformis, KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 39–40.

Gillette, common; Askew, one shell. Widely distributed throughout the Eocene and Miocene of the Atlantic Coastal Plain.

CRUCIBULUM CONSTRICTUM (Conrad)
Plate 85, figure 15; plate 86, figures 4, 5, 8

Dispotaea constricta CONRAD, *1842*, Proc. Nat. Inst., Bull. 2, p. 194, pl. 1, fig. 2.

Gillette, common. Maryland (St. Mary's).

CREPIDULA PLANA Say
Plate 85, figure 21

Crepidula plana SAY, *1822*, Acad. Nat. Sci. Philadelphia Jour., vol. 2, p. 226.

Gillette, rare (young). Common in Coastal Plain deposits from the Chesapeake group to the Recent. This is the first record from the basal Miocene.

CREPIDULA FORNICATA (Linné)
Plate 85, figure 20

Patella fornicata LINNÉ, *1758*, Systema Naturae, Ed. 10, p. 781.

Gillette, rare (young); Askew common. Common along the Atlantic Coastal Plain from the Chesapeake group (Miocene) to the Recent. This is apparently the earliest record for the species.

TURRITELLA FUERTA Kellum

Turritella fuerta KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 40, pl. 10, figs. 8, 9.

Gillette, very common; Askew, a few shells. Trent only.

POTAMIDES SILVERDALENSIS Richards, n. sp.
Plate 85, figure 13

Shell elevated, tapering; type and only specimen incomplete. Rugose, with irregular concentric growth lines on all whorls preserved (four). Growth lines crossed by conspicuous cross lines giving a reticular appearance to the shell. Main concentric lines separated from each other by fainter secondary lines. Two prominent knobs extend the length of the shell.

Length of type (ANSP 15846), 23.0 mm. (incomplete); width of body whorl, 13.0 mm.

Type locality, Gillette marl pits, Silverdale, N. C.

Similar to *P. campanulatus* Heilprin (Tampa limestone) but easily distinguished by the more conspicuous coarse ribs and its consequent reticular appearance.

EUPLEURA HARBISONI Richards, n. sp.
Plate 85, figure 18

Shell small, fairly stout, 5 whorls, suture very distinct with whorls abruptly shouldered. Aperture as in *E. caudata* Say but less thickened. Concentric striations finer and closer together than in *E. caudata*. Aperture teeth not well shown, although there are faint indications of five.

Length of type (ANSP 15852), 26.0 mm.; width, 9.0 mm.

Type locality, Gillette marl pits, Silverdale, N. C.

This may possibly be the ancestor of the Pliocene, Pleistocene and Recent *E. caudata* Say.

Named in honor of Miss Anne Harbison, of the Academy of Natural Sciences, who has been studying East Coast Miocene faunas.

MUREX DAVISI Richards, n. sp.
Plate 85, figures 1, 2

Shell subfusiform; six convex whorls; three elevated varices on body whorl with a longitudinal rib between. Between the two varices nearest the aperture there are five indistinct ribs. No spines. Aperture more than half the length of the shell; canal deflected to the left. Surface of the shell covered with alternating thick and thin revolving lines. Seven aperture teeth.

Length of type (ANSP 15836), 45.0 mm.; width, 29.0 mm. Paratype (NCSM).

M. millvillensis Richards and Harbison from the Kirkwood formation of New Jersey is a related species, but is smaller and has revolving lines in groups of three separated by slightly thicker lines. The aperture aud canal of the two species are similar.

M. tritonopsis Heilprin from the Tampa linestone is also smaller and has the spiral lines farther apart. Also the canal is much straighter.

Named in honor of Harry T. Davis, Director of the North Carolina State Museum, who took part in the field work.

MUREX KELLUMI Richards, n. sp.
Plate 85, figures 3, 4

Shell subfusiform, five whorls, three varices, two to four ribs between the varices. Revolving lines prominent. Primary concentric ridges are separated from each other by two narrow grooves. Aperture suboval, with canal slightly deflected to the left. Ten aperture teeth. Conspicuous groove to the left of the canal.

Length of type (ANSP 15838), 42.5 mm.; width, 25.0 mm.

The type and unique shell is badly worn. The species is apparently not related to any other *Murex* from the North Carolina Miocene. It is closest to an undescribed *Murex* from the Miocene of Santo Domingo (ANSP 4003). *M. kellumi* occurs with *M. davisi* but is easily distinguished by its coarser ribs, less deflected aperture, greater number of aperture teeth and its more slender shape.

Named in honor of Dr. L. B. Kellum, who originally worked on the Trent fauna.

CORALLIOPHILA CUMBERLANDIA (Gabb)
Plate 85, figures 24, 25

Cantharus cancellaria GABB, *1860*, Acad. Nat. Sci. Philadelphia Jour., ser. 2, vol. 4, p. 375, pl. 67, fig. 6.

Gillette, a few broken specimens. New Jersey (Kirkwood); Maryland (Choptank, St. Mary's).

ECPHORA QUADRICOSTATA (Say)
Plate 85, figure 16

Fusus quadricostata SAY, *1824*, Acad. Nat. Sci. Philadelphia Jour., vol. 4, p. 127, pl. 7, fig. 5.

Gillette, one broken shell. Maryland (St. Mary's).

RAPANA VAUGHANI Mansfield
Plate 85, figure 6

Rapana vaughani MANSFIELD, *1937*, Florida Geol. Survey Bull. 15, p. 137, pl. 5, fig. 6.

Gillette, common; Askew, common. Miocene: North Carolina (Trent); Florida (Tampa).

RAPANA GILLETTI Richards, n. sp.
Plate 85, figure 5

Shell rather small, spire conic, canal fairly long. The last whorl comprises the major part of the shell. Spirally sculptured with four prominent raised ribs. Spiral lines about uniform in strength and farther apart

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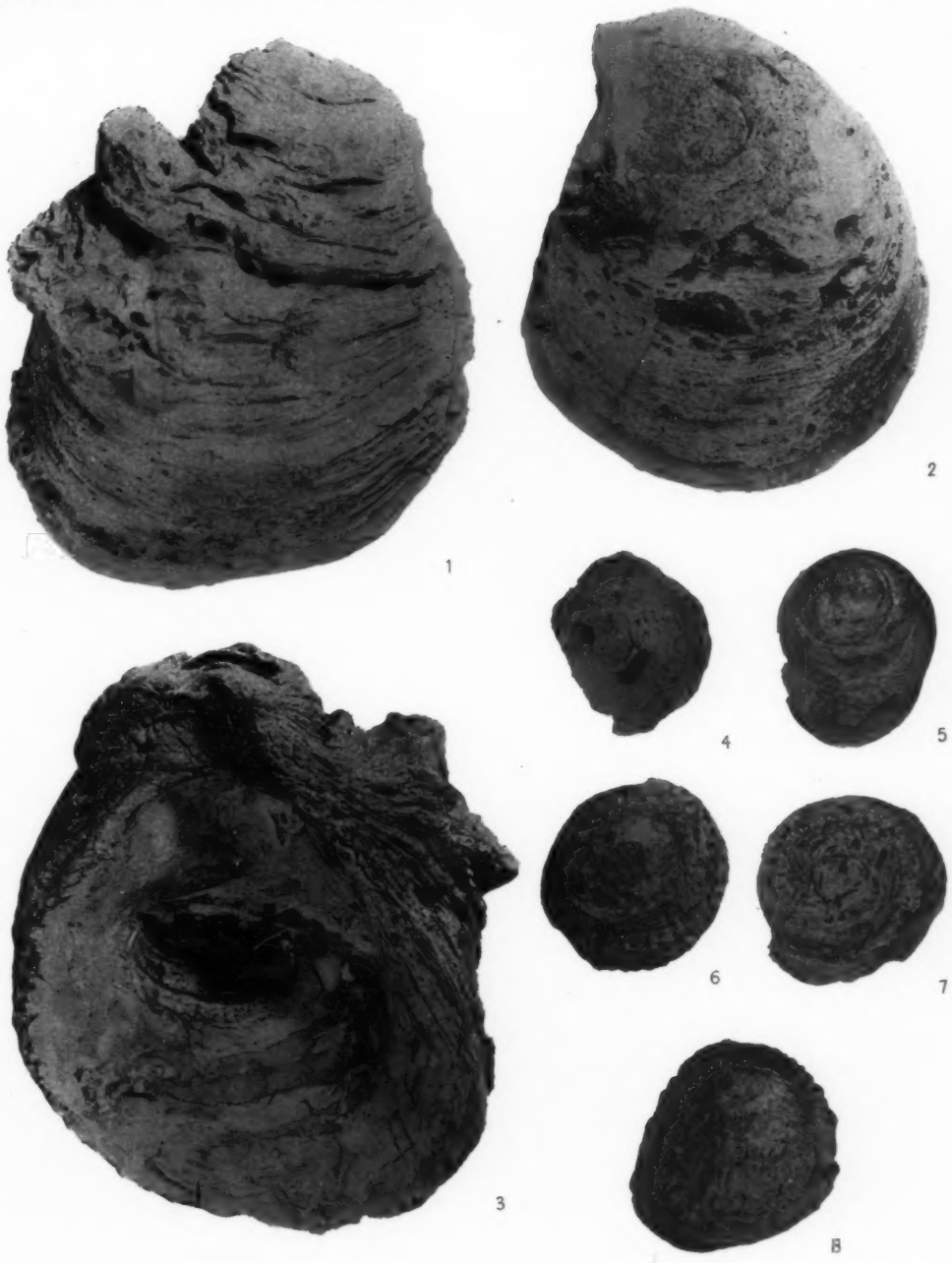
EXPLANATION OF PLATE 86

All specimens from Gillette marl pits, Silverdale, N. C.

FIGS. *1–3—Ostrea georgiana* Conrad, var.? *1, 3*, NCSM, ×½. *2*, ANSP 15857, ×1. (p. 519)
4, 5, 8—Crucibulum constrictum (Conrad). *4*, ANSP 15849, ×1. *5*, NCSM, ×1. *8*, ANSP 15849, ×1. (p. 523)
6, 7—Calyptraea trochiformis Lamarck. ANSP 15848, ×1. (p. 523)



Richards, Miocene (Trent) Mollusca

than in *R. vaughani*. Pillar provided with a callus with a small chink between the pillar callus and the siphonal fasciole. Faint dentitions on the inner margin of the aperture.

Length of type (ANSP 15840), 23.5 mm.; width, 13.0 mm. Paratype (NCSM).

Type locality, Gillette marl pits, Silverdale, N. C.

Differs from *R. vaughani* Mansfield by the greater distance between the spiral ribs, the absence of secondary striations, and by the four conspicuous raised ribs instead of the greater number as in *R. vaughani*. The wide space between the ribs in *R. gilletti* is clearly shown near the base of the shell.

Found with *R. vaughani*, but not as common.

Named in honor of Mr. John Gillette, owner of the marl pits at the type locality.

BUSYCON SPINIGER ONSLOWENSIS Kellum

Busycon spiniger onslowensis KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 40, pl. 11, figs. 1–3.

Gillette, fairly common; Askew, a few shells. Trent only.

LYRIA CAROLINENSIS Kellum

Lyria carolinensis KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 40, pl. 11, figs. 4, 5.

Gillette, reported by Kellum; not found by present survey. Trent only.

SCAPHELLA STROMBOIDELLA Kellum

Scaphella stromboidella KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 41, pl. 11, figs. 6, 7.

Gillette, fairly common; Askew, a few shells. Trent only.

SIPHONALIA MIGRANS (Conrad)
Plate 85, figure 19

Fusus migrans CONRAD, *1843*, Acad. Nat. Sci. Philadelphia Proc., vol. 1, p. 309.

Gillette, one broken shell. Maryland (Calvert).

FUSINUS TRENTENSIS Richards, n. sp.
Plate 85, figures 11, 12

Shell elongate; about six whorls, striated with nine longitudinal ribs; spiral lines conspicuous and approximately equidistant and separated from each other by fainter interspacial lines. Suture appressed; last whorl elongate; canal short and narrow.

Length of type (ANSP 15856), 26.5 mm.; width, 12.0 mm. Paratype (NCSM).

Type locality, Gillette marl pits, Silverdale, N. C.

Differs from *F. exilis* (Conrad) from the Miocene of Maryland by having more regular spiral ribs and by its less conspicuous nodes. In *F. exilis* the nodes are only on the upper four whorls, while in *F. trentensis* they are on all six. The new species also resembles *F. ballista* Dall from the Tampa limestone of Florida but is distinguished by its less distinct nodes.

OLIVA POSTI Dall
Plate 85, figure 9.

Oliva posti DALL, *1915*, U. S. Nat. Mus. Bull. 90, p. 45, pl. 12, fig. 24.
Oliva posti, KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 41.

Gillette, fairly common. North Carolina (Trent); Florida (Tampa).

OLIVELLA GARDNERAE Richards, n. sp.
Plate 85, figure 10

Shell of medium size, slender, with high conical spire; five whorls, all smooth, sutures deeply channeled. Body whorl comprises about two-thirds of the shell; margin of the outer lip of aperture nearly straight but curved at lower extremity. Aperture extends about half the length of the shell and is roughly triangular in shape. Anterior third of body whorl is provided with an enamel which forms a ridge approximately at right angles to the axis of the shell. Lower portion of columella with a callus.

Length of type (ANSP 15832), 8.0 mm.; width, 3.0 mm. Length of paratype (NCSM) 9.0 mm.; width, 3.5 mm.

Type locality, Gillette marl pits, Silverdale, N. C.

Similar to *O. mississippinesis* Conrad from the Eocene but is more slender and tapering and with fewer markings near the base of the shell. Also related to *O. brooksvillensis* Mansfield (Tampa limestone) but more slender and distinguished by its aperture, which is more triangular and which does not extend along as much of the shell as *O. brooksvillensis*.

Named in honor of Dr. Julia Gardner of the United States Geological Survey.

TEREBRA WHITFIELDI Martin
Plate 85, figures 22, 23

Terebra curvilineata whitfieldi MARTIN, *1904*, Maryland Geol. Survey, Miocene, p. 140, pl. 40, figs. 15–17.

Gillette, rare; two imperfect specimens. New Jersey (Kirkwood); Maryland (Calvert).

CONUS POSTALVEATUS Kellum

Conus postalveatus KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 41, pl. 11, figs. 8–10.

Gillette, very common; Askew, common. Trent only.

LEIOSTRICHUS sp.
Plate 85, figure 14

One broken individual of an undetermined species of *Leiostrichus* was obtained from the Gillette pits.

ADDITIONAL TRENT LOCALITIES

With the exception of *Pecten trentensis* Harris and *P. elixatus* (Conrad) from 6 miles below Pollocksville, N. C., all the above species were obtained from the vicinity of Silverdale, Onslow County, N. C. The present report does not attempt to discuss the faunas of the other Trent localities studied during the recent field survey. It is hoped that a full report will be published by the North Carolina State Museum at some future time. It may be noted, however, that Kellum listed five additional fossil localities in Onslow and Jones Counties where poorly preserved Trent fossils were obtained. In addition to some of the species listed in this paper, Kellum recorded some undetermined species of *Glycymeris*, *Cardium* and *Panope*.

RELATIONSHIP OF TRENT FAUNA

The present study tends to confirm the view of Kellum that the Trent fauna is most closely related to that of the Tampa limestone of Florida, of Lower Miocene age. A slightly more distant relationship is shown to the next higher Miocene deposits such as the Kirkwood of New Jersey, the Calvert of Maryland and the Alum Bluff group of Florida. The relationship to the Oligocene is thought to be more distant than that to the Miocene.

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KELLUM, L. B., 1926, Paleontology and stratigraphy of the Castle Hayne and Trent marls of North Carolina: U. S. Geol. Survey Prof. Paper 143.

JOURNAL OF PALEONTOLOGY, VOL. 17, NO. 5, PP. 527–543, PLS. 87–95, 1 TEXT FIG., SEPTEMBER, 1943

UPPER JURASSIC AMMONITES FROM THE PLACER DE GUADALUPE DISTRICT, CHIHUAHUA, MEXICO

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ABSTRACT—Thick near-shore deposits of Upper Jurassic age in the Placer de Guadalupe district of eastern Chihuahua have furnished 15 species of ammonites belonging to three distinct stratigraphic positions. The middle Kimmeridgian is represented by three species of *Waagenia*, identical with species from the Mazapil region of Zacatecas The lower Portlandian is represented by two species of *Subplanites* and four species of *Virgatosphinctes*, which greatly resemble species from the Portlandian of Bavaria and India. Associated with these is a rasenid that is indistinguishable from the lower and middle Kimmeridgian genus *Involuticeras*. The upper Portlandian is represented by five species of *Kossmatia*, of which some attain much larger size than any previously described. Some of the species of *Virgatosphinctes* and *Kossmatia* are identical with species obtained near Mazapil, Zacatecas, and afford a definite correlation with that region. The *Subplanites* apparently mark a distinct faunal zone, higher than the upper Kimmeridgian beds bearing *Mazapilites*, lower than the upper Portlandian beds bearing *Kossmatia*, and corresponding to the upper part of the range of *Aulacosphinctoides*.

INTRODUCTION

DURING June 1933, W. S. Adkins and R. E. King made a reconnaissance study of the Cuchillo Parado and the Placer de Guadalupe districts bordering the lower part of the Río Conchos of eastern Chihuahua (fig. 1). They intended to write a joint paper on the geology and paleontology of the districts, but Adkins found insufficient time to study the fossils and consequently, in 1940, turned them over to the Federal Geological Survey for purposes of correlation and description. The writer has undertaken the study of these fossils and as an initial contribution now presents a description of the Jurassic fossils, of which all are from the Placer de Guadalupe district. The type material has been deposited in the collections of the United States National Museum.

Many thanks are due Messrs Adkins and King for the privilege of making these studies, which afford a surer correlation of rocks of similar age in the United States and which contribute to our knowledge of the history of the Mesozoic Mexican geosyncline.

FOSSIL LOCALITIES

Upper Jurassic fossils from five localities (see fig. 1) in the Placer de Guadalupe district of eastern Chihuahua have been recorded by the Texas Bureau of Economic Geology as follows.

Locality 17252.—East side of Puerto Azul, about 2 miles west of Los Fresnos del Río ranch and 15 miles south-southeast of Placer de Guadalupe. Upper part of Upper Jurassic shale and sandstone.

Locality 17253.—Same locality as 17252 but about 50 meters lower stratigraphically.

Locality 17254.—Near Puerto Azul, about 1 mile west of Los Fresnos del Río ranch and 15 miles south-southeast of Placer de Guadalupe. Brownish-black, platy limestone interbedded in shale. Middle part of Upper Jurassic shale and sandstone.

Locality 17258.—Near Kansas City, Mexico, and Orient Railroad, at kilometer 119¼ about 2 miles northwest of Picachos and 7 miles east of Placer de Guadalupe. Upper part of Upper Jurassic shale and sandstone.

Locality 17259.—Strike valley about one-third of a mile east of the road from Placer de Guadalupe to San Sóstenes and about 2 miles northeast of Placer de Guadalupe. Upper part of Upper Jurassic shale and sandstone.

CORRELATION

The Jurassic ammonites from the Placer de Guadalupe district of eastern Chihuahua represent the Kimmeridgian and Portlandian stages. The occurrence of the ammonites here and of similar forms elsewhere is shown on the distribution chart.

The oldest fossils, obtained at locality 17254, consist of crushed specimens of *Waagenia* preserved in brownish-black,

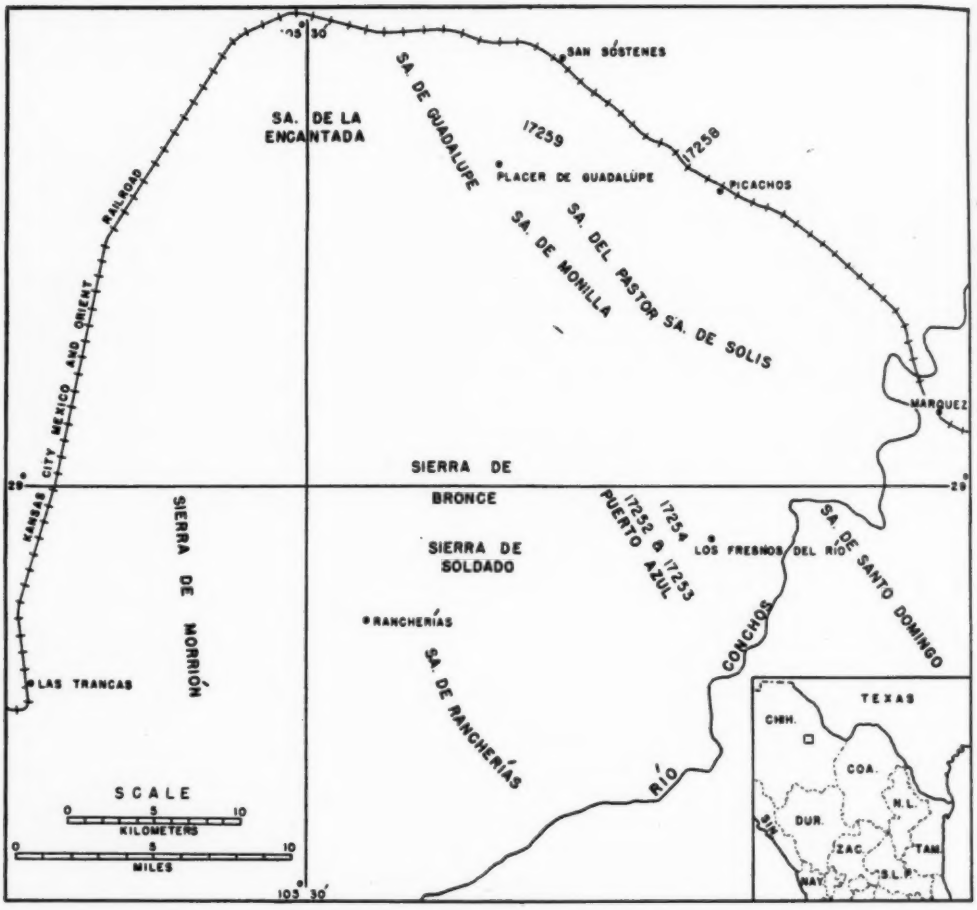


FIG. *1*—Index map of Placer de Guadalupe district. Locations of Jurassic fossils are indicated by numbers assigned by Texas Bureau of Economic Geology.

platy limestone. The species appear to be identical with those described by Burckhardt (1906, pp. 104, 105; pl. 27, figs. 2–5) from the region of Mazapil, Zacatecas, and include *Waagenia* cf. *W. knopi* (Neumayr), *W.* cf. *W. beckeri* (Neumayr), and *W.* cf. *W. harpephora* (Neumayr). Spath (1931, p. 463) notes that

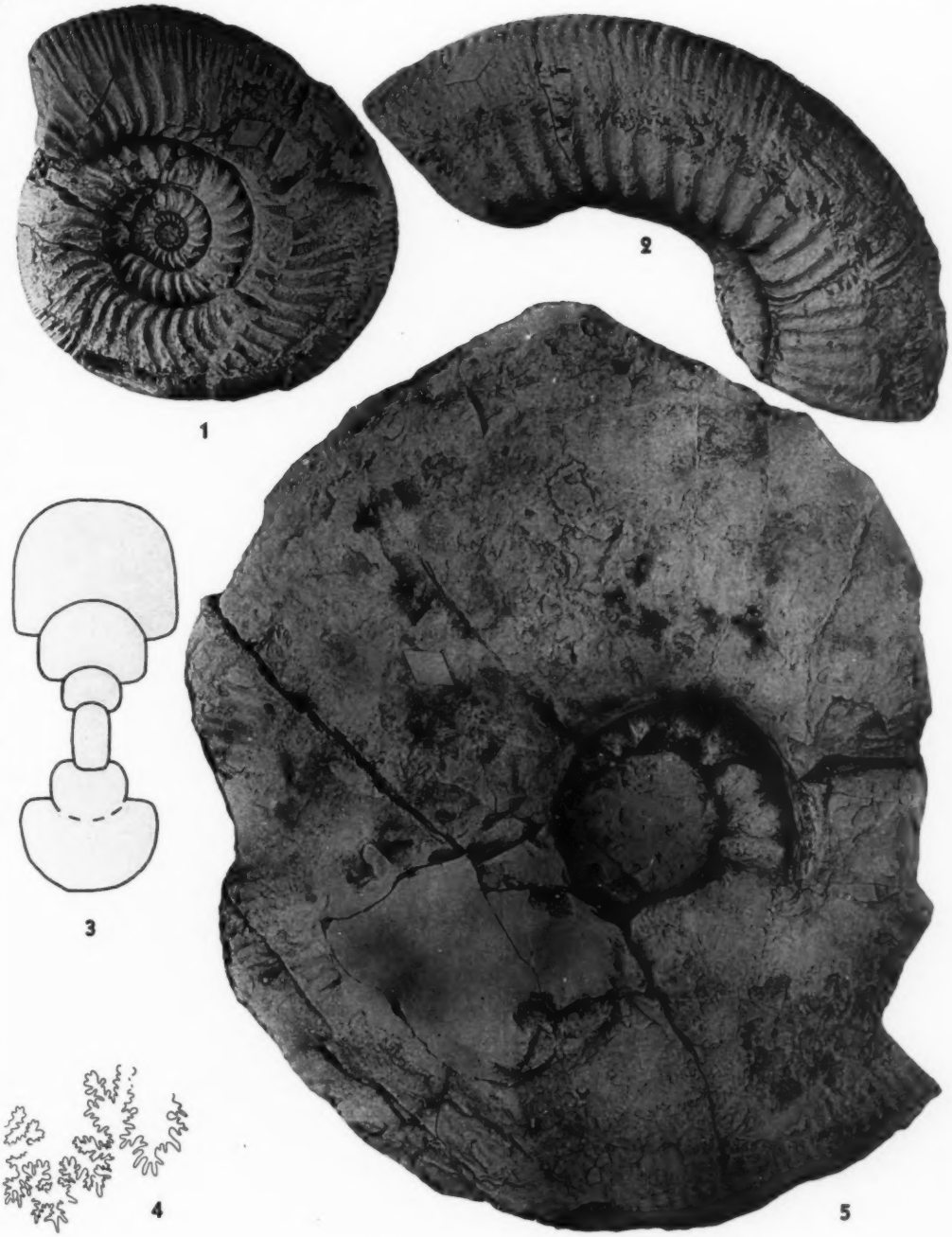
> *Waagenia* has been found already in the lower Kimmeridgian (White Jura Gamma); and it is almost certain that it ranged up into the upper Kimmeridgian, although its maximum development is in the *beckeri* and *steraspis* zones,

i. e., upper middle Kimmeridgian as defined by Spath (1933, p. 846). In Mexico the genus *Waagenia* has been found only in the upper part of the middle Kimmeridgian

EXPLANATION OF PLATE 87

FIGS. *1–3*—*Virgatosphinctes adkinsi* Imlay, n. sp. From 2 miles west of Los Fresnos del Río Ranch. Texas Bureau Econ. Geology loc. 17252, ×¾. *1, 3*, Lateral view and cross section of holotype, U. S. Nat. Mus. 103359, ×¾. *2*, Lateral view of paratype, U. S. Nat. Mus. 103360, ×¾. (p. 534)

4, 5—*Involuticeras picachosense* Imlay, n. sp. From 2 miles northwest of Picachos. Texas Bureau Econ. Geology loc. 17258. Suture and lateral view of holotype, U. S. Nat. Mus. 103352, ×¾. (p. 532)



Imlay, Upper Jurassic Ammonites

1

2

3

4

Imlay, Upper Jurassic Ammonites

DISTRIBUTION AND COMPARISON OF UPPER JURASSIC AMMONITES FROM EASTERN CHIHUAHUA, MEXICO

Species from eastern Chihuahua	Localities					Similar species	Occurrence of similar species	Age of similar species
	17252	17253	17254	17258	17259			
Waagenia cf. *W. knopi* (Neumayr)			×			*W. knopi* (Neumayr)	Southern Europe	Middle Kimmeridgian
W. cf. *W. beckeri* (Neumayr)			×			*W. beckeri* (Neumayr)	Southern Europe	Middle Kimmeridgian
W. cf. *W. harpephora* (Neumayr)			×			*W. harpephora* (Neumayr)	Southern Europe	Middle Kimmeridgian
Involuticeras picachosense Imlay				×		*I. praecursor* (Burckhardt)	Zacatecas	Middle Kimmeridgian
Subplanites fresnosensis Imlay	×			×		*S. schlosseri* (Schneid)	Bavaria	Lower Portlandian
S. aff. *S. reisi* (Schneid)	×					*S. reisi* (Schneid)	Bavaria	Upper Kimmeridgian?
Virgatosphinctes guadalupensis Imlay	×					*V. himalayanus* Uhlig	India	Portlandian
V. adkinsi Imlay	×					*V. kraffti* Uhlig	India	Portlandian
V. chihuahuensis Imlay	×					*Perisphinctes* aff. *P. transitorus* Oppel (Burckhardt)	Zacatecas	Lower Portlandian
V. cf. *V. denseplicatus* (Waagen)	×					*V. denseplicatus* (Waagen)	India	Portlandian
Kossmatia varicostata Imlay	×	×				*K. victoris* (Burckhardt)	Zacatecas	Upper Portlandian
K. aff. *K. varicostata* Imlay					×			
K. kingi Imlay	×	×			×	"*Perisphinctes*" sp. ind. Burckhardt	Zacatecas	Upper Portlandian
K. rancheriasensis Imlay		×						
K. cf. *K. alamitosensis* (Castillo and Aguilera)		×				*K. alamitosensis* (Castillo and Aguilera)	San Luis Potosí	Upper Portlandian

directly above beds containing *Glochiceras fialar* (Oppel).

The Portlandian is represented by fossils from localities 17252, 17253, 17258 and 17259, which may be listed as follows:

Locality 17252:
- *Subplanites fresnosensis* Imlay
- *Subplanites* aff. *S. reisi* (Schneid)
- *Virgatosphinctes guadalupensis* Imlay
- *Virgatosphinctes adkinsi* Imlay
- *Virgatosphinctes chihuahuensis* Imlay
- *Virgatosphinctes* cf. *V. denseplicatus* (Waagen)
- *Kossmatia varicostata* Imlay
- *Kossmatia kingi* Imlay
- *Kossmatia* cf. *K. alamitosensis* (Castillo and Aguilera)

Locality 17253:
- *Kossmatia varicostata* Imlay
- *Kossmatia kingi* Imlay
- *Kossmatia rancheriasensis* Imlay

Locality 17258:
- *Involuticeras picachosense* Imlay

EXPLANATION OF PLATE 88

FIGS. *1–4—Subplanites fresnosensis* Imlay, n. sp. *1*, Cross section of paratype. From 2 miles northwest of Picachos. Texas Bureau Econ. Geology loc. 17258, U. S. Nat. Mus. 103355, ×¾. *2, 4*, Suture and lateral view of paratype. From 2 miles west of Los Fresnos del Río Ranch. Texas Bureau Econ. Geology loc. 17252, U. S. Nat. Mus. 103354, ×¾. *3*, Lateral view of paratype. From 2 miles west of Los Fresnos del Río Ranch. Texas Bureau of Econ. Geology loc. 17252, U. S. Nat. Mus. 103354, ×¾. (p. 532)

Subplanites fresnosensis Imlay
Locality 17259:
Kossmatia aff. *K. varicostata* Imlay
Kossmatia kingi Imlay

The collection from locality 17258 contains *Involuticeras picachosense* Imlay and *Subplanites fresnosensis* Imlay, preserved in a grayish-brown to reddish limestone matrix. The specimen of *Involuticeras* has been slightly smashed laterally but not appreciably distorted, and the *Subplanites* is undeformed. Judging from their preservation, these ammonites might have come from the same bed, but such an association would be contrary to the known ranges of the genera. In Europe, *Involuticeras* occurs in the *Streblites tenuilobatus* zone (Salfeld, 1917, p. 72), which represents the upper part of the lower Kimmeridgian. In Mexico the genus has been recorded from about the same or perhaps a slightly higher stratigraphic position (Burckhardt, 1906, pp. 98–102; Imlay, 1939, p. 41) in association with *Glochiceras fialar* (Oppel). The range of *Subplanites*, according to Spath (1933, pp. 850, 864), is from the upper part of the *Neochetoceras sterapis* zone to the *Provirgatites scythicus* zone, that is, late Middle Kimmeridgian to Lower Portlandian. As the known ranges of *Subplanites* and *Involuticeras* do not overlap, it seems likely that the specimens in question were collected from different beds. However, it is possible that *Involuticeras* has a much greater range in the Jurassic deposits of Mexico than in Europe.

The collection from locality 17252 contains *Subplanites*, *Virgatosphinctes*, and *Kossmatia*, which constitute a very unlikely association. *Subplanites* range from the late middle Kimmeridigian to the lower Portlandian. *Virgatosphinctes* ranges through the Portlandian and Tithonian, according to Spath (1933, p. 850), but Burckhardt (1906, pp. 110, 146, 147) records *V. aguilari* from directly above the *Waagenia* beds, which shows that the genus ranges into the upper Kimmeridgian. *Kossmatia* ranges from the upper Kimmeridgian (*Subplanites contiguus*) zone to the basal Berriasian (Mazenot, 1939, p. 130) but reached its greatest development in the upper Portlandian. The species of *Subplanites* and *Virgatosphinctes* from locality 17252 are similar to or identical with species from the lower Portlandian of the Mazapil region of Zacatecas. Thus, *S.* aff. *S. reisi* (Schneid) is probably identical with *Perisphinctes* cf. *P. danubiensis* Schlosser in Burckhardt (1906, p. 112, pl. 32, fig.1), *V. adkinsi* Imlay with *Virgatites* sp. in Burckhardt (1906, p. 119, pl. 30, fig. 4), and *V. chihuahuensis* Imlay with *Perisphinctes* aff. *P. transitorius* Oppel in Burckhardt (1906, p. 113, pl. 30 fig. 8). Similar close comparisons of *Kossmatia* from locality 17252 can be made with species from the upper Portlandian of the Mazapil region. *Kossmatia varicostata* Imlay is very similar to *K. victoris* Burckhardt (1906, p. 131, pl. 26, figs. 1–6, pl. 27, fig. 1), and *K. kingi* Imlay is probably identical with *Perisphinctes* sp. ind. in Burchardt (1906, p. 130, pl. 37, figs. 9, 11, 12). In Mexico, *Kossmatia* has been recorded previously only from beds of upper Portlandian age, and the species are like the upper Portlandian species of the Himalayan region rather than the long-ranging *K. richteri* (Oppel) and its varieties from southern Europe. Examination of the fossils from locality 17252 shows that the specimens of *Kossmatia* are preserved in a grayish-black limestone matrix and are only slightly distorted, whereas the specimens of *Subplanites* and *Virgatosphinctes* are preserved in a light grayish-brown limestone matrix and are strongly distorted. This difference in preservation suggests that *Kossmatia* comes from a different bed than the other genera. On the basis of known generic ranges and of similar species elsewhere in the world, the species of *Subplanites* and *Virgatosphinctes* would be placed in the lower Portlandian and the species of *Kossmatia* in the upper Portlandian. This arrangement would be satisfactory, except that *Kossmatia* from locality 17253 occurs 50 meters lower in the section than locality 17252. Perhaps this occurrence can be explained by overturning of the beds. Perhaps it is due to carelessness in labeling, as one of the fragments marked 17253 fitted exactly on a fragment marked 17252.

The species of *Kossmatia* in collections 17253 and 17259 are preserved in the same grayish-black limestone matrix as those from collection 17252 and undoubtedly represent the upper Portlandian.

The species of *Subplanites* and *Virgatosphinctes* from eastern Chihuahua are identical with or very similar to those in the phosphatic limestone unit 7 of the section in Cañón de San Matías about 6 miles southeast of Mazapil, Zacatecas (Burckhardt, 1906, pp. 155, 156). Burckhardt (1906, pp. 168–170) at first considered that this unit corresponded to the beds containing *Mazapilites* and numerous *Aspidoceras* of the same region, but later recognized (1930, p. 48, tab. 4) that it was higher stratigraphically. Following Spath (1933, pp. 796, 864), the writer (1939, tables 7 and 10) formerly correlated it with the upper Kimmeridgian, but Spath was misled by Burckhardt's earlier erroneous correlation. In the Cañón del Toboso section (Imlay, 1939, pp. 9–11, fig. 4), 2½ miles east of Symón, Durango, the writer found a specimen of *Virgatosphinctes* that is probably identical specifically with *V. mexicanus* (Burckhardt) (1906, p. 115, pl. 31, figs 5–9) from unit 7 of the section in Cañón de San Matías. The specimen of *Virgatosphinctes* from the Cañón del Toboso section occurs 4 feet below the top of the writer's unit 8. It is associated with *Aulacosphinctoides* ("*Torquatisphinctes*" sp.) and occurs about 18 feet above the highest bed with *Mazapilites* and 31 feet below the bed with *Kossmatia*. From the overlying unit 9, Emil Böse obtained the many species of *Aulacosphinctoides* described by Burckhardt (1919 pp. 16–40; 1921, pls. 5–14) but the genus ranges downward in the same section as low as the top of the *Waagenia* beds. Thus, the species of *Subplanites* and *Virgatosphinctes* discussed herein belong to a distinct faunal zone that is higher than the beds with *Mazapilites*, lower than the beds with *Kossmatia*, and corresponds to the upper part of the range of *Aulacosphinctoides*. Their age is most probably lower Portlandian rather than upper Kimmeridgian (Bononian), as indicated (1) by comparisons with the most similar Eurasion species, (2) by the abundance of *Virgatosphinctes*, (3) by their position at the top of the local range of *Aulacosphinctoides*, whose known world range is Portlandian and Kimmeridgian, and (4) by a stratigraphic position much nearer the beds with *Kossmatia* (upper Portlandian) than the beds with *Waagenia* (middle Kimmeridgian).

The faunal and stratigraphic relations of the fossils discussed herein are shown in the stratigraphic table.

UPPER JURASSIC FAUNAL AND STRATIGRAPHIC RELATIONS IN NORTHERN MEXICO

European stages after L. F. Spath (1933)		Formations of northern Mexico	Faunal divisions of northern Mexico	
Tithonian		La Casita	*Substeueroceras* and *Proniceras*	*Micracanthoceras*
			Kossmatia and *Durangites*	
Portlandian		sandstones, shales, marls	*Subplanites*	*Aulacosphinctoides*
	Upper		*Mazapilites*	
Kimmeridgian	Middle		*Waagenia*	
			Glochiceras fialar and *Idoceras durangense*	
	Lower		*Idoceras* gr. of *balderus*	
		?	*Sutneria* gr. of *platynota*	
Upper Oxfordian		La Gloria	*Dichotomosphinctes*	
Middle Oxfordian		sandstones and limestones	*Indosphinctes?*	

SYSTEMATIC DESCRIPTIONS

Genus WAAGENIA Neumayr, 1878

WAAGENIA spp.

This genus is represented by many small, much compressed specimens preserved in a brownish-black platy limestone and identical specifically with the forms that Burckhardt (1906, pp. 103–105, pl. 27, figs. 1–5) compared with *Waagenia harpephora* (Neumayr), *W. knopi* (Neumayr), and *W. beckeri* (Neumayr). Their occurrence, according to W. S. Adkins and R. E. King, is hundreds of feet lower than the beds at localities 17252 and 17253, from which were obtained *Subplanites*, *Virgatosphinctes*, and *Kossmatia*. This great interval is in striking contrast to the tens of feet separating the same faunas in Zacatecas and southeastern Durango.

Specimens: U. S. Nat. Mus. 103349, 103350, 103351.

Occurrence: Upper Jurassic shale and sandstone. Texas Bureau of Economic Geology locality 17254, Placer de Guadalupe district, eastern Chihuahua, Mexico.

Genus INVOLUTICERAS Salfeld, 1913

INVOLUTICERAS PICACHOSENSE Imlay, n. sp.

Plate 87, figures 4, 5

Shell large, discoidal, much compressed; whorls wedge-shaped in section, much higher than wide, thickest at edge of umbilicus, embracing about four-fifths; flanks lightly convex, sloping gently toward a narrowly rounded venter. Umbilicus narrow; wall moderately high, vertical, rounding abruptly into flanks. Incomplete body chamber represented by one-third of outer whorl of figured specimen.

Ornamentation of innermost whorls unknown, On outer whorls the ornamentation becomes effaced anteriorly. In the umbilicus are exposed wide, strong, irregularly spaced ribs, which begin on the umbilical wall and attain greatest prominence on the umbilical shoulder. On the outer whorl these umbilical ribs weaken anteriorly and become indistinct. Middle of flanks nearly smooth, marked only by broad, faint, irregular swellings that connect umbilical ribs with ventral ribs. Venter and upper part of flanks marked by many low, broad ribs that are slightly wider than the interspaces. These ribs have a gentle forward inclination on the flanks but cross the venter transversely without diminution in strength. Faint constrictions present on outer whorl. Sutures poorly preserved but showing a very broad first lateral lobe and narrow first lateral saddle.

The holotype has been crushed laterally somewhat but at a diameter of 175 mm. has a whorl height of about 75 mm., a whorl diameter of about 50 mm. and an umbilical width of 45 mm.

This species differs from the smaller *Involuticeras praecursor* Burckhardt by its much finer ventral ribbing, which persists to a later growth stage, by its coarser umbilical ribbing, and by its wider first lateral lobe. Its ornamentation is much like that of *Craspedites limitis* Burckhardt (1930, p. 110; 1903, p. 52, pl. 8, fig. 5, pl. 9, figs. 1, 2) from the upper Kimmeridgian of Argentina, but its whorl section is much higher, and its first lateral lobe is much wider. The much larger *Involuticeras tenuiplexus* (Quenstedt) (188, p. 995, pl. 111, figs. 3 and m[1]) has a very similar suture line.

Holotype: U. S. Nat. Mus. 103352.

Occurrence: Upper Jurassic shale and sandstone. Texas Bureau of Economic Geology locality 17258, Placer de Guadalupe district, eastern Chihuahua, Mexico.

Genus SUBPLANITES Spath, 1910

SUBPLANITES FRESNOSENSIS Imlay, n. sp.

Plate 88, figures 1–4; pl. 89, fig. 5

This species is represented by six specimens, of which most are somewhat distorted. Whorls subovate in section, wider than high, embracing about one-third, thickest on lower third of flank; flanks gently convex; venter broadly rounded. Umbilicus very wide; wall moderately high, steeply inclined, rounding evenly into flanks. Body chamber probably represented by last whorl of holotype.

The ribs begin at the line of involution, curve backward on the umbilical wall, recurve forward considerably on the flanks, but cross the venter nearly transversely. They are very strong at all stages of growth and are not reduced along the midventral line. On the smallest known whorls (pl. 2, fig. 3) most of the ribs bifurcate near the

middle of the flanks, but some remain simple, the primary ribs are not much stronger than the secondary ribs, and the interspaces are not greatly wider than the ribs. During growth, the place of branching rises to the upper third of the flank, trichotomous ribs appear, the primary ribs become much stronger than the secondary ribs, and the interspaces become two to three times as wide as the ribs. On the largest whorls nearly all the primary ribs branch trichotomously, and the rib bundles are separated on the venter by one or two intercalary ribs. In trichotomous rib bundles the anterior branch generally arises lower than the others. Constrictions present on inner whorls.

Suture line complex. First lateral lobe asymmetrical, long, slender, terminating in three main branches, slightly longer than siphonal lobe. Second lateral lobe very small, somewhat shorter than the first auxiliary lobe. Siphonal saddle fairly broad, asymmetrically divided by a secondary lobe. First lateral saddle narrow, as high as external saddle. Second lateral saddle much lower than first.

The posterior end of the specimen shown on plate 88, figure 4, which has been only slightly compressed, has a whorl height of 56 mm. and a whorl thickness of 58 mm. An undistorted specimen (pl. 88, fig. 1) has a whorl height of 56 mm. and a whorl thickness of 65 mm.

This species compares in coarseness of ribbing with *Subplanites schlosseri* (Schneid) (1915b, p. 14, pl. 1, figs 1–1c) but its ribs, incline forward more strongly and bifurcate higher on the flanks, and its whorl section is thicker. *S. danubiensis* (Schlosser) (1882, p. 63, pl. 9, figs. 3, 3a) has somewhat finer ribbing.

Types: Holotype, U. S. Nat. Mus. 103353; 2 paratypes, U. S. Nat. Mus. 103354a, b; figured specimen, U. S. Nat. Mus. 103355.

Occurrence: Upper Jurassic shale and sandstone. Texas Bureau of Economic Geology localities 17252 an 17258, Placer de Guadalupe district, eastern Chihuahua, Mexico.

SUBPLANITES aff. S. REISI (Schneid)
Plate 91, figure 1

Perisphinctes cf. *P. danubiensis* Schlosser. Burckhardt, *1906*, Inst. geol. México Bol. 23, p. 112, pl. 32, fig. 1.

This species is represented by six distorted fragments. The figured specimen shows parts of three whorls, of which the outer bears considerable shell material. Whorls subtrapezoidal in section, a little higher than wide, embracing about two-fifths. Umbilicus wide; wall fairly high and vertical.

The ribs on the inner whorls are narrow high, prorsiradiate, dichotomous, reduced in strength along the midventral line, and separated by interspaces about twice their width. The ribs on the outer whorls are strong, fairly widely separated, incline backward on umbilical wall and forward on the flanks, branch virgatomously near or somewhat above the middle of the flanks, and are not reduced in strength on the venter. The rib bundles are separated on the venter by one or two intercalary ribs. Constrictions present on inner whorls.

This species may be distinguished from *Subplanites fresnosensis* Imlay by its finer, more closely spaced ribbing at all growth stages. It bears considerable resemblance to *S. malarguensis* Spath (1931, p. 468; Burckhardt, 1903, p. 36, pl. 4, figs. 1–6) from Argentine, but has coarser ribbing and a higher whorl section. *Subplanites reisi* (Schneid) (1915a, p. 162, pl. 8, figs. 1, 1a) has equally coarse ribbing and a similar whorl section.

Figured specimen: U. S. Nat. Mus. 103356.

Occurrence: Upper Jurassic shale and sandstone. Texas Bureau of Economic Geology locality 17252, Placer de Guadalupe district, eastern Chihuahua, Mexico.

Genus VIRGATOSPHINCTES Uhlig, 1910
VIRGATOSPHINCTES GUADALUPENSIS Imlay, n. sp.
Plate 90, figures 1–6

This species is represented by seven internal molds that show the various growth stages. Whorls depressed, subquadrate in section, wider than high, embracing nearly one-half, thickest near umbilical wall; flanks gently convex on inner whorls, somewhat flattened on outer whorls; venter broadly rounded. Umbilicus wide; wall low, vertical, rounding abruptly into flanks.

The ribs are nearly radial on the umbilical wall, incline rather strongly forward on the flanks, and cross the venter with a gentle forward arching. Branching occurs near or above the middle of the flanks. Virgatomous ribs are present at a diameter of 42 mm. and may occur earlier. At greater diameters, virgatomous ribs are about twice as abundant as dichotomous. On the largest whorls some primary ribs give rise to bundles of four secondary ribs, of which one may terminate freely between bundles on the opposite flank. The primary ribs are broad, moderately prominent, and irregularly spaced. On the inner whorls the interspaces are slightly wider than the primary ribs and narrower than the secondary ribs, but anteriorly they become wider spaced. On the outer whorls the interspaces are three to four times as wide as the primary ribs and a little wider than the secondary ribs. No diminution in strength of ribbing along the midventral line is apparent. Constrictions present on the innermost whorls.

Most of the specimens are too deformed. for accurate measurements, but the specimen shown on plate 90, figures 1, 3, 5 has a whorl height of 42 mm. and a whorl thickness of 48 mm.

This species is distinguished from *Virgatosphinctes adkinsi* Imlay by its higher whorl section and its less prominent and more irregularly spaced ribbing. It is rather similar to *V. himalayanus* Uhlig (1910a, p. 330, pl. 64, figs. 1 a–c) but develops virgatomous ribs at a somewhat earlier growth stage and probably has flatter flanks. *Virgatosphinctes mexicanus* (Burckhardt) (1906, p. 115, pl. 31, figs. 5–9) is less involute and has sharper ribs, which branch lower on the flanks.

Types: Holotype, U. S. Nat. Mus. 103357; 3 paratypes, U. S. Nat. Mus. 103358a, b, c.

Occurrence: Upper Jurassic shale and sandstone. Texas Bureau of Economic Geology locality 17252, Placer de Guadalupe district, eastern Chihuahua, Mexico.

VIRGATOSPHINCTES ADKINSI Imlay, n. sp.

Plate 87, figures 1–3

?Virgatites sp. Burckhardt, *1906*, Inst. geol. México Bol. 23, p. 119, pl. 30, fig. 4.

This species is represented by four internal molds on which are preserved considerable shell material. Whorls depressed subcircular in section, wider than high, embracing a little over one-half, thickest near umbilical wall; flanks gently convex; venter broadly rounded. Umbilicus moderately wide; wall low, vertical, rounding abruptly into flanks.

The ribs begin at the line of involution, curve backward on the umbilical wall, and curve forward rather strongly on the flanks. This forward curvature becomes less pronounced with growth. Virgatomous, or less commonly dichotomous branching occurs at, or somewhat below, the middle of the flanks. No simple ribs observed. Trichotomous ribs are present at a diameter of about 20 mm. The primary ribs are strong, high, and separated by interspaces about three times their width. The secondary ribs are high, rounded and separated by interspaces of equal width. All ribs cross the venter with a gentle forward arching and are faintly reduced in strength along the midventral line. Several narrow, deep constrictions on each whorl.

The holotype at a diameter of 81 mm. has a whorl height of 27 mm., a whorl thickness of 33 mm., and an umbilical width of 35 mm.

This species is characterized by its low whorl section and its high, strongly prorsiradiate primary ribs. On the internal mold the ribs are sharper than on the shell and greatly resemble those on the specimen figured by Burckhardt as *Virgatites* sp. The only other Mexican species that needs comparison is *V. guadalupensis* Imlay, which has a higher whorl section and more reduced ribbing. *Virgatosphinctes kraffti* Uhlig (1910a p. 335, pl. 53 figs. 4a–d; pl. 62, figs. 1a, b, 2a–c) has slightly weaker ribbing and a higher whorl section, but its general appearance is strikingly similar.

Types: Holotype, U. S. Nat. Mus. 103359; paratype, U. S. Nat. Mus. 103360.

Occurrence: Upper Jurassic shale and sandstone. Texas Bureau of Economic Geology locality 17252, Placer de Guadalupe district, eastern Chihuahua, Mexico.

VIRGATOSPHINCTES CHIHUAHUENSIS Imlay, n. sp.

Plate 91, figures 2–5

Perisphinctes aff. *P. transitorius* Oppel in Burck-

hardt, *1906*, Inst. geol. México Bol. 23, p. 113, pl. 30, fig. 8.

This species is represented by five internal molds, which preserve some of the shell material. Form discoidal, compressed; whorls subovate in section, a little wider than high, embracing nearly one-half, thickest near umbilical wall; flanks gently convex; venter moderately broad and evenly rounded. Umbilicus wide, fairly shallow; wall low and vertical, rounding abruptly into flanks.

Ornamentation of inner whorls, as seen in umbilical opening, consists of high, rather narrow ribs which begin at the line of involution, curve backward on the umbilical wall, and incline forward on the flanks. On the outer whorls the ribbing is similar but somewhat sharper. Most of the ribs bifurcate at or a little above the middle of the flanks. A few ribs are virgatomous and rarely some are simple. All ribs cross the venter without diminution in strength. About three or four narrow, deep constrictions per whorl.

Siphonal lobe deeper than first lateral lobe and having two long, straight end branches. First lateral lobe broad, deeper than second lateral, and divided subsymmetrically into three branches. Second lateral lobe long and narrow. There are three oblique auxiliary lobes. Siphonal saddle fairly broad, divided into two branches, with outer branch larger than inner. First lateral saddle with two nearly equal branches.

Dimensions of holotype (pl. 91, figs. 2–4) and paratype (pl. 91, fig. 5) are, respectively; greatest diameter, 86 and 142 mm.; whorl height, 24 and 50 mm.; whorl thickness, 26 and 55? mm.; umbilical width, 43 and 58 mm.

This species is very similar to an Argentinian species (Steiner, 1897, p. 32, pl. 15 figs. 6, 7; Burckhardt, 1903, p. 40, pl. 5, figs. 4–9; Weaver, 1931, p. 415, pl. 45, fig. 306) commonly compared with *Aulacosphinctes transitorius* (Oppel) (Zittel, 1868, p. 103, pl. 22, figs. 1–6) but is distinguished by the complete lack of a ventral groove. The Argentinian species differs from *V. chihuahuensis* by its greater number of virgatomous ribs, by its gently forward arching ribs on the venter, and by its much smaller second lateral lobe. *Virgatosphinctes saheraensis* Spath (1931, p. 537, pl. 96, figs. 1a, b) has a higher whorl section and develops slightly coarser ribbing on the outer whorl.

Types: Holotype, U. S. Nat. Mus. 103361; paratype, U. S. Nat. Mus. 103362.

Occurrence: Upper Jurassic shale and sandstone. Texas Bureau of Economic Geology locality 17252, Placer de Guadalupe district, eastern Chihuahua; La Caja formation, Cañón de San Matías near Casa Sotelo in Santa Rosa Valley, about 6 miles southeast of Mazapil, Zacatecas, Mexico.

VIRGATOSPHINCTES cf. V. DENSEPLICATUS (Waagen)

Plate 89, figures 1–4

This species is represented by the two figured specimens. Whorls subquadrate in section, a little higher than wide, embracing about one-third, thickest near umbilical wall; flanks flattened, subparallel; venter broadly rounded. Umbilicus wide; wall low, steeply inclined.

Ornamentation consists of fine, high, closely spaced ribs, which start at the line of involution, incline forward strongly on the flanks, but cross the venter nearly transversely. About two-thirds of the ribs bifurcate near the middle of the flanks, and the rest remain simple. Virgatomous ribs observed only immediately posterior to constrictions. All ribs are slightly reduced in strength along the midventral line. Constrictions are pronounced and numerous. The specimen shown on plate 3, figure 4, at a diameter of 130 millimeters has a whorl height of 40 mm., a whorl thickness of 38 ? mm., and an umbilical width of 60 mm.

The only comparable densely ribbed Mexican species is *Virgatosphinctes aguilari* (Burckhardt) (1906, p. 110, pl. 27, figs. 6–9) which has a broader, rounder whorl section, and is much more involute.

Reineckeia striolata Steur (1897, p. 36, pl. 14, figs. 8–10) has nearly identical ribbing but is described as having elongate ventral tubercles. The Mexican form here described is somewhat finer ribbed and more compressed than most of the Indian varieties of *V. denseplicatus* (Waagen) (1875, p. 201, pl. 46, figs. 3a, b; pl. 55, figs. 1a, b; Uhlig, 1910a, p. 313, pl. 53, figs. 3a–d; pl. 54, figs. 1a–c;

pl. 55, figs. 1a–d, 2a–d, 3a–d; pl. 56, figs. 1a–c; Spath, 1931, p. 532, pl. 77, figs. 3a–c; pl. 90, fig. 1; pl. 96, figs. 3a, b; pl. 102, fig. 4) but is possibly like the finely ribbed variety *striatissima* (Spath, 1931, p. 534) which has similar proportions.

Figured specimens; U. S. Nat. Mus. 103363a, b.

Occurrence: Upper Jurassic shale and sandstone. Texas Bureau of Economic Geology locality 17252, Placer de Guadalupe district, eastern Chihuahua, Mexico.

Genus KOSSMATIA Uhlig, 1910

Kossmatia has been recorded from many places in a broad equatorial belt extending from New Zealand through southern Eurasia, northern Africa, northern South America, and southern North America. The occurrences in New Zealand and central Argentina are about as far south of the equator as the occurences in northern California and in the northern Alps of Europe are north of the equator (Uhlig, 1910a, pp. 275–278; 1910b, pp. 547, 600; Burckhardt, 1912, pp. 131–138; Spath, 1923, pp. 302–307; Krantz, 1928, pp. 34–36; Roman, 1936, p. 12; Mazenot, 1939, pp. 129, 130). Nowhere throughout this vast extent, as shown by published records, does *Kossmatia* attain as great diversity in size, form, and sculpture as in Mexico. The number of species now known from Mexico far exceeds those known from all other parts of the world. Their study has made possible a better understanding of the genus than has hitherto been possible and has shown its distinctness from similar-appearing genera, such as *Berrisella*, *Substeueroceras*, and *Parodontoceras*, with which it may be associated, and with which it has been confused.

Kossmatia was first defined by Uhlig (1910a, pp. 267, 275) without designating a genotype but listing four representative species, of which three were from the late Upper Jurassic, and one was from the Middle Jurassic. Subsequently, the latter species, *Stephanoceras eucycla* Waagen, was placed by Spath (1924, p. 8) in his genus *Eucycloceras*. Another of these species, *Ammonites tenuistriatus* Gray, that corresponds more closely to Uhlig's definition of *Kossmatia*, was formally selected by Roman (1938, p. 326) as a genotype of *Kossmatia*,

The most comprehensive study of the American species of *Kossmatia* was made by Burckhardt, (1912, pp. 131–138) who redefined the genus and added considerable information concerning its development. However, most of his Mexican specimens are internal molds of immature forms that are difficult to compare with the published figures of more mature forms from Europe and Asia. This fact, plus Uhlig's failure to designate a genotype, has undoubtedly influenced the claims that *Kossmatia* is poorly defined, that its Eurasian species (Gerth, 1925, p. 82; Roman, 1938, p. 217) are not generically identical with the American species, and that it does not deserve more than subgeneric rank under *Berriasella* (Roman, 1936, p. 12; Mazenot, 1939, pp. 124, 130).

Studies of the American species referred to *Kossmatia* show that the genus, based on *Ammonites tenuistriatus* Gray as genotype, is really present, that it possesses characteristics which distinguish it clearly from other genera of the Palaehoplitidae, and that the apparent differences between the Eurasian Alpine-Mediterranean species and the American species are a result of the much greater variation in form and sculpture among the latter. Some of the American species, however, are very similar to the Eurasian species, as Burckhardt (1912, pp. 131–138; 1930, table 10) has already pointed out. Thus, *Kossmatia interrupta* Burckhardt (1912, p. 134, pl. 34, figs. 2, 3, 15) and *K. alamitosensis* (Castillo and Aquilera) (1895, p. 30, pl. 21, figs. 4, 6) are like *K. richteri* (Oppel) (Zittel, 1868, p. 108, pl. 20, figs. 9a–d). *Kossmatia flexicostata* (Castillo and

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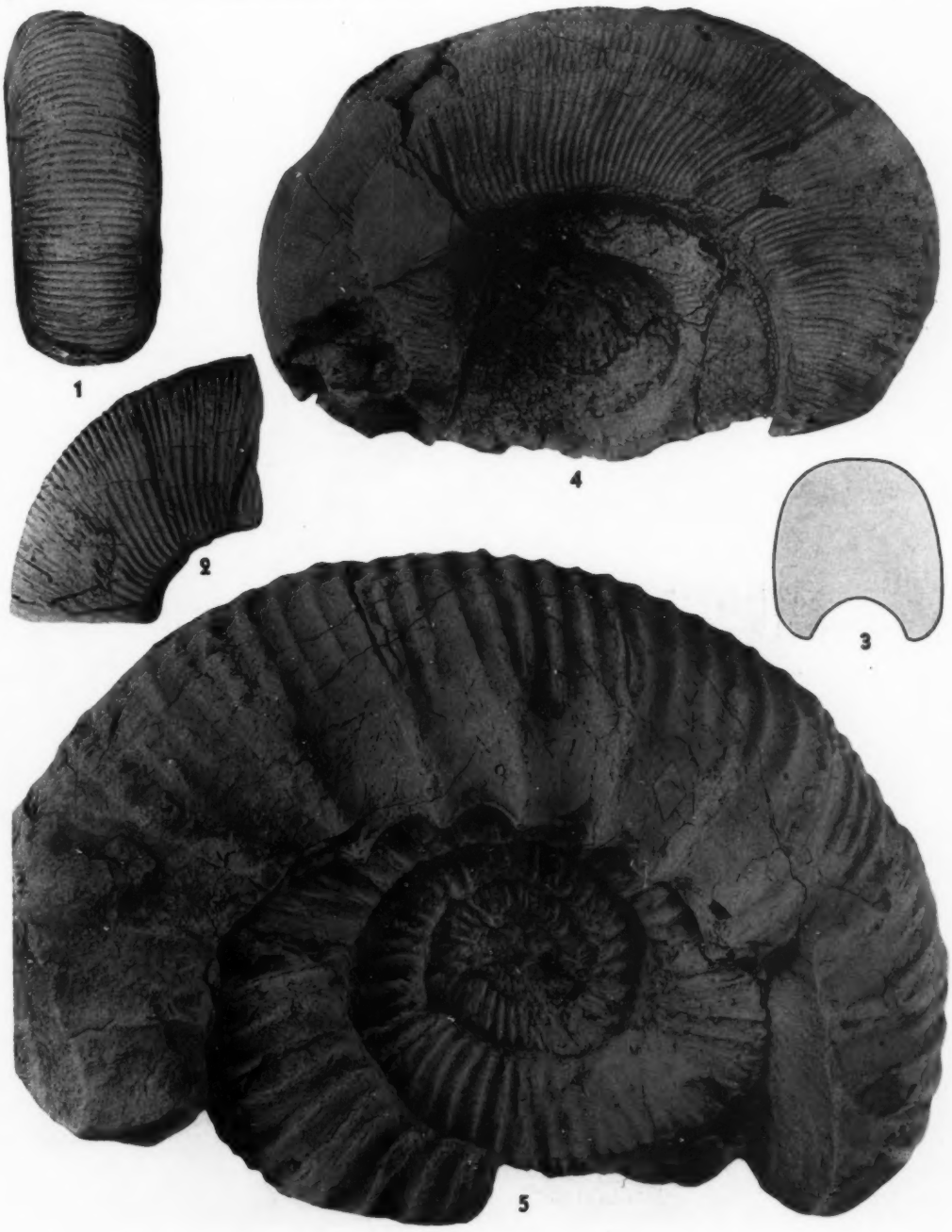
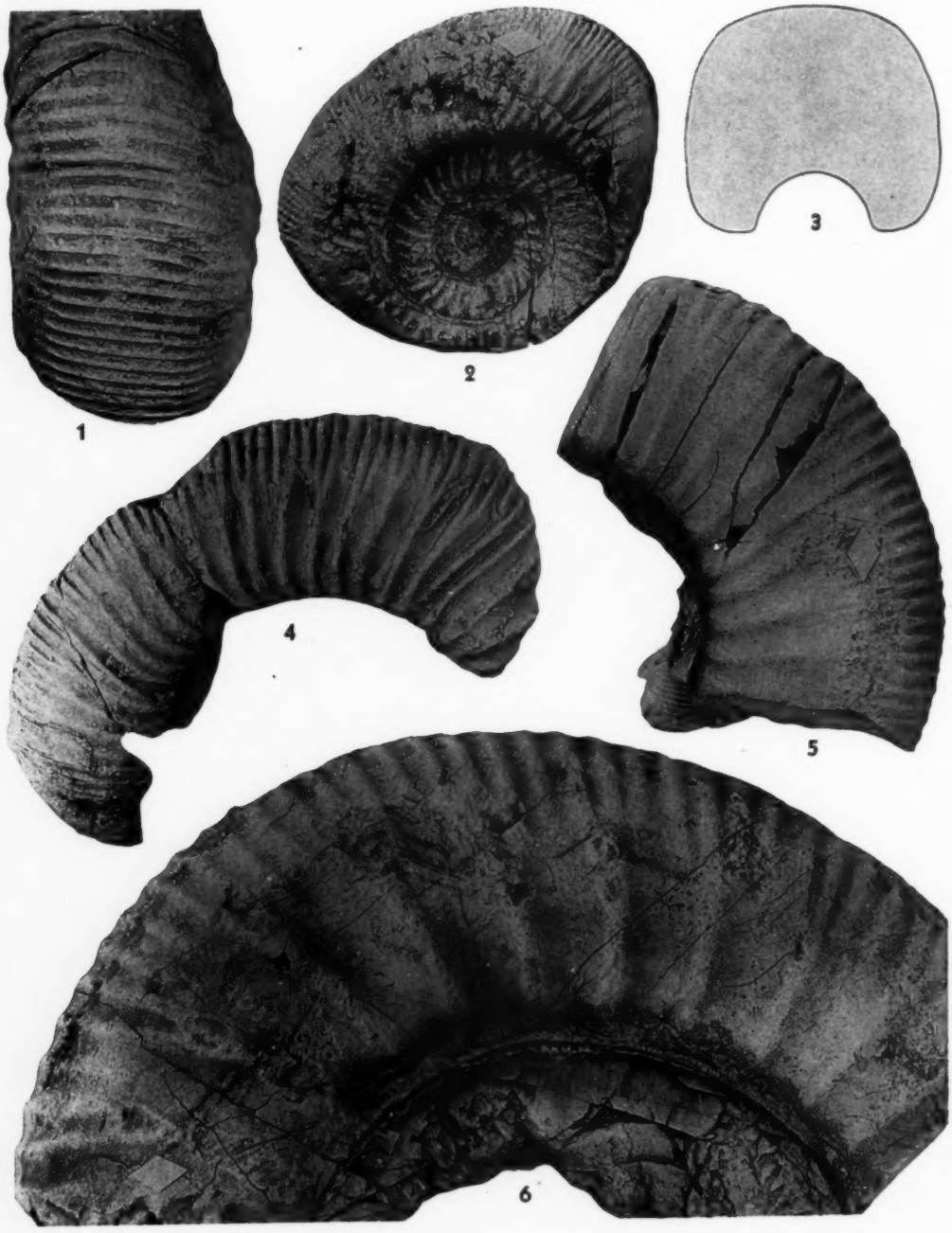
EXPLANATION OF PLATE 89

FIGS. *1–4—Virgatosphinctes* cf. *V. denseplicatus* (Waagen). From 2 miles west of Los Fresnos del Río Ranch. Texas Bureau Econ. Geology loc. 17252, ×¾. *1–3*, Ventral and lateral views and cross section of specimen, U. S. Nat. Mus. 103363a. *4*, Lateral view of specimen, U. S. Nat. Mus. 103363b. (p. 535)

5—Subplanites fresnosensis Imlay, n. sp., Holotype, ×¾. From 2 miles west of Los Fresnos de Río Ranch. Texas Bureau Econ. Geology loc. 17252, U. S. Nat. Mus. 103353. (p. 532)



Imlay, Upper Jurassic Ammonites



Imlay, Upper Jurassic Ammonites

Augilera) (1895, p. 29, pl. 13, fig. 1) and *K. victoris* (Burckhardt) (1906, p. 131, pl. 36, figs. 1–6; pl. 37, fig. 1) are similar to *K. tenuistriata* Gray (Uhlig, 1910a, p. 275, pl. 91, figs. 3a, b).

Those writers who consider that the American species referred to *Kossmatia* are generically distinct from the Alpine-Mediterranean spedies have noted the following differences; (1) The American species have a flattened or even concave venter that may be marked by a smooth midventral area, whereas the Alpine-Mediterranean species have a perfectly rounded venter. (2) In the former, the ribs on the venter meet at an angle, or form a linguiform sinus along the midline, whereas in the latter they merge gradually. (3) Some of the American species bear tubercles at the bifurcation points of the ribs.

None of these suggested differences is worthy of generic distinction. The venter on immature whorls, such as those on which most of Burckhardt's Mexican species are based, may be evenly to broadly rounded. On mature whorls, it is generally narrowly rounded, with its sides diverging outward to the subparallel flanks. On some mature whorls it is somewhat flattened along the midline, as in *K. desmidoptycha* Uhlig (1910a, p. 277, pl. 47, figs. 2a–d; pl. 91, fig. 4) from India and *K victoris* (Burckhardt) (1906, p. 131, pl. 36, figs 1–6, pl. 37, fig. 1) from Mexico. Mature whorls on which the shell is preserved do not bear a pronounced depression or a smooth area along the midline of the venter, although some species show a faint thinning of the ribs. However, internal molds of both mature and immature whorls may have a conspicuous, smooth midventral area. *Kossmatia zacatecana* Burckhardt (1912, p. 136, pl. 34, figs. 4–6, 11–13, 16, 17, 20), *K. interrupta* Burckhardt (1912, p. 134, pl. 34, figs. 2, 3, 15), and *K. pectinata* Burckhardt (1912, p. 135, pl. 34, figs. 1, 7–10, 14) have a smooth midventral area on the internal molds, but the ribs cross the venter uninterrupted in places where the shell is preserved. Examination of the type specimen of *K. aulleri* Stanton (1895, p. 82, pl. 18, figs. 6, 7) likewise reveals that the ventral groove is confined to the internal mold and does not exist where the actual shell is preserved. A ventral groove is not shown in any of the illustrations of the Alpine-Mediterranean species, although Roman (1936, p. 13) notes that it exists in the young of *K. richteri* Oppel. The immature form of *K. pseudodesmidoptycha* Krantz (1928, p. 35, pl. 1, figs. 5a–c) at a diameter of 7.5 millimeters has a broad, smooth band along the venter. Specimens of comparable size of other species of *Kossmatia* have not been illustrated and are not known to the writer.

The supposition is likewise invalid that the American species differ from the Alpine-Mediterranean species by the chevronlike arrangement of the ribs along the venter. The chevron effect is highly variable and is most apparent on the internal molds where the ribs are apt to be interrupted. Where the shell is preserved the ribs from adjoining flanks meet along the midline to form a forwardly projecting subangular sinus that varies from gentle to pronounced or even linguiform. On most species it is gentle in the inner whorls and becomes pronounced on the outer whorls. On some species, such as *K. flexicostata* (Castillo and Augilera) (1895, p. 29, pl. 13, fig. 1) and *K. desmidoptycha* (Uhlig) (1910a, p. 277, pl. 47, figs. 2a–d; pl. 91, fig. 4) the sinus remains gentle on the outer whorls.

None of the North American species bears tubercles at the furcation points of the ribs. The greatest height of the ribs is generally near the middle of the flanks, which is likewise the most common place of furcation. On the immature whorls of *K. burkarti* Burckhardt, *K. zacatecana* Burckhardt, *K. pectinata* Burckhardt, and *K.*

EXPLANATION OF PLATE 90

FIGS. *1–6*—*Virgatosphinctes guadalupensis* Imlay, n. sp. From 2 miles west of Los Fresnos del Río Ranch. Texas Bureau Econ. Geology loc. 17252, ×¾. *1, 3, 5*, Ventral view, cross section, and lateral view of paratype, U. S. Nat. Mus. 103358. *2*, Lateral view of paratype, U. S. Nat. Mus. 103358. *4*, Lateral view of paratype, U. S. Nat. Mus. 103358. *6*, Lateral view of holotype, U. S. Nat. Mus. 103357. (p. 533)

kingi Imlay, the furcation points are high and lamelliform but are not tuberculated. Neither are there any umbilical tubercles, despite the statement by Gerth (1925, p. 82) to the contrary. The aberrant South American species, *K. pseudodesmidoptycha* Krantz is possibly an exception, as an immature form at a diameter of 7.5 mm. bears lateral tubercles. Comparisons with other species cannot be made as forms of similar size have not been described.

In summation, the American species referred to *Kossmatia* do not differ generically from the Alpine-Mediterranean species, and some of them are very similar. They are more numerous and as a consequence show greater variation in form and sculpture. This variation has been well discussed by Burckhardt (1912, pp. 131–133), who, however, did not distinguish clearly between the ornamentation of the internal mold and that of the shell and did not have available any specimens as large as those described herein.

As now understood, *Kossmatia* includes moderate to large flattened forms that have typically a high whorl section, flattened, subparallel flanks, and a narrowly rounded venter. The inner whorls by contrast are depressed and well rounded. The amount of involution ranges from one-fourth to one-half. The width of the umbilicus ranges from about 30 to 50 percent of the diameter. The ribbing ranges from fine to coarse, is strongest near the middle of the flanks, becomes stronger with growth, and is generally coarsest on stout-whorled species. The ribs incline backward on the umbilical wall, are nearly straight on the lower two thirds of the flanks, and arch forward strongly on the upper part of the flanks and venter to form a subangular sinus that ranges from broad to narrow, or is even linguiform on some adults. Rib branching occurs near the middle of the flanks and may be dichotomous or virgatomous. Simple and intercalary ribs are common in some species. The branching points in early growth stages are strong, but in late stages become indistinct. A ventral groove is not present on the shell, except possibly during the earliest growth stages, but is pronounced on the internal mold. A faint reduction of the ribbing along the midventral line occurs on the immature whorls of some species. Constrictions are present on the inner whorls and are most pronounced on the coarsely ribbed species. The suture is similar to that of other genera of the Berriasellinae (Mazenot, 1939, pp. 28, 32; Burckhardt, 1912, p. 133). It is characterized by the siphonal lobe being generally at least as long as the first lateral lobe, by the small second lateral lobe, and by the wide siphonal saddle.

Kossmatia most nearly resembles *Parodontoceras* and *Substeueroceras*, with which it may be associated. *Parodontoceras* may be distinguished from *Kossmatia* (1) by its venter being more regularly rounded in the adult and (2) by its ribs being coarser, generally wider-spaced, predominately dichotomous or unbranched rather than virgatomous, and arched forward only slightly on the venter. *Substeueroceras* may be distinguished from *Kossmatia* (1) by its venter being broader and generally flatter and (2) by its ribs being finer, more flexuous, branched at various levels from the umbilicus to the upper third of the flanks, never virgatomous, generally only slightly arched forward on the venter, and tending to disappear on the body whorl.

Kossmatia is reported from beds ranging in age from upper Kimmeridgian (Bononian) to the basal Berriasian, but most of the species occur in the Portlandian. The Himalayan species described by Uhlig are associated with genera which suggest a late Portlandian or early Tithonian age, but stratigraphic details are still to be worked out, and probably beds of both ages are represented. The Mexican species have

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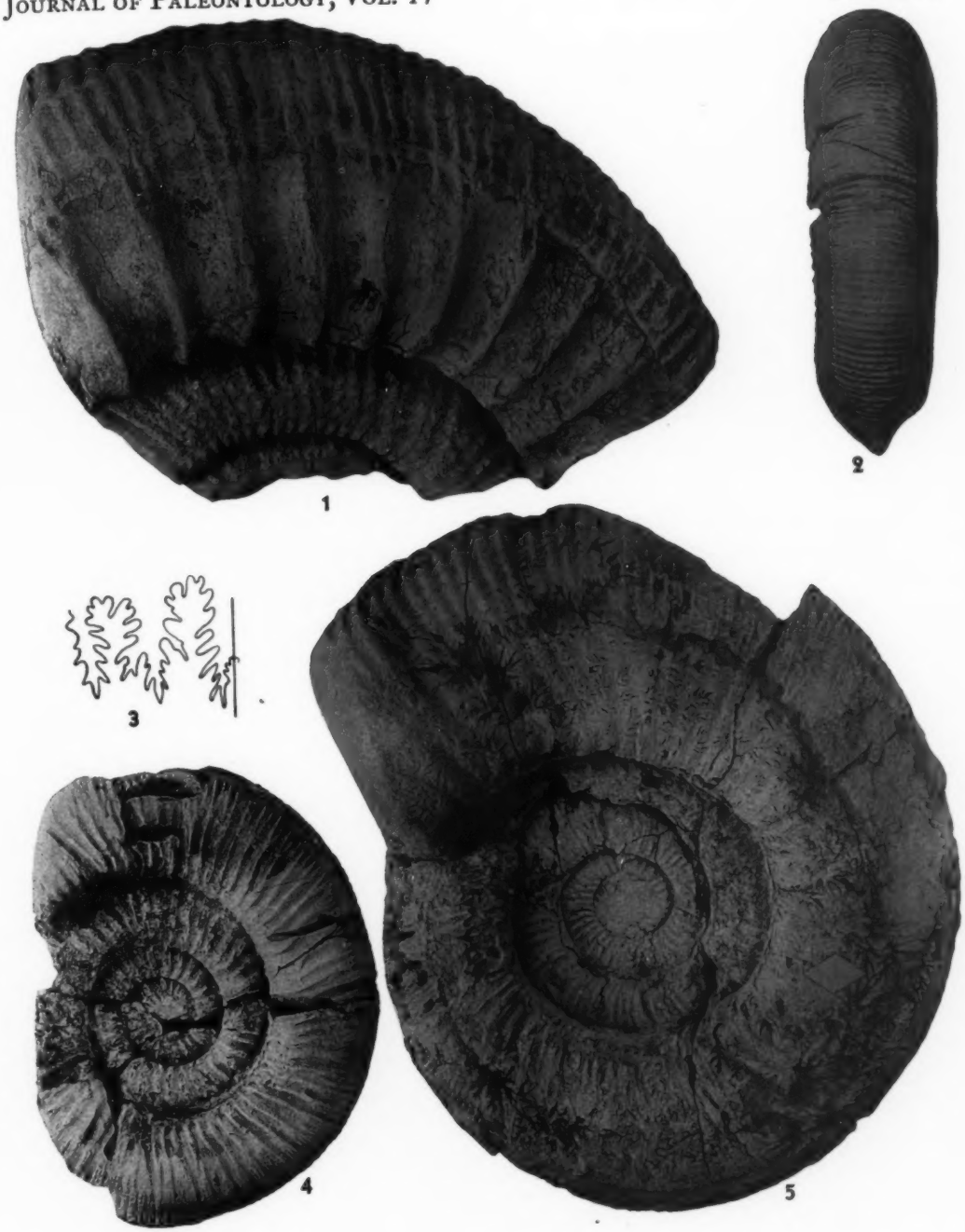
EXPLANATION OF PLATE 91

FIG. *1*—*Subplanites* aff. *S. reisi* (Schneid). Lateral view of specimen from 2 miles west of Los Fresnos del Río Ranch, Texas Bureau Econ. Geology loc. 17252, U. S. Nat. Mus. 103356, ×¾. (p. 533)

2–5—*Virgatosphinctes chihuahuensis* Imlay, n. sp. From 2 miles west of Los Fresnos del Río Ranch. Texas Bureau Econ. Geology loc. 17252, ×¾. *2*, *4*, Ventral and lateral views of holotype, U. S. Nat. Mus. 103361. *3*, *5*, Suture and lateral view of paratype, U. S. Nat. Mus. 103362. (p. 534)



Imlay, Upper Jurassic Ammonites

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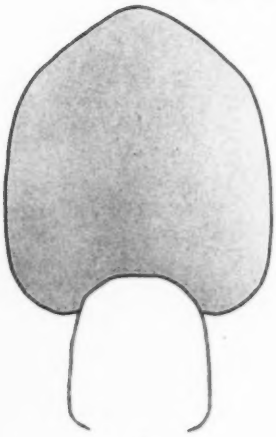

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4

Imlay, Upper Jurassic Ammonites

been placed definitely by the detailed stratigraphic studies of Burckhardt in the upper Portlandian just below the beds with *Substeuroceras* and above the beds with *Aulacosphinctoides*. The California species, *Kossmatia dilleri* Stanton, has been placed (Anderson, 1932, pp. 316–318; 1933, p. 1253) in the Portlandian thousands of feet below beds containing early Lower Cretaceous fossils. The Argentinan species of *Kossmatia* described by Krantz are probably of upper Portlandian age, as they occur directly below beds containing *Substeuroceras*. In the Alpine-Mediterranean deposits of southern Europe and northern Africa the genus is represented by *Kossmatia richteri* (Oppel in Zittel) (Mazenot, 1939, pp. 129, 130) which has been interpreted very broadly and is said to range from the upper Kimmeridgian to the basal Berriasian. Roman (1936, p. 12) notes that the variety from the upper Kimmeridgian (*Subplanites contiguus* zone) is distinguished from the typical form in younger beds by its higher whorls, narrower umbilicus and denser ribbing. It seems likely to the writer that some of the late Tithonian and early Berriasian forms assigned to *Kossmatia* probably belong to *Parodontoceras* or to *Subthurmannia*, of which some species have *Kossmatia*-like ribbing on the venter. *Subthurmannia* should be easy to distinguish because of its early *Thurmannites*-stage characterized by a sulcate venter, umbilical tubercles, and bidichotomous ribbing, but fragmentary specimens might be difficult to place generically.

KOSSMATIA VARICOSTATA Imlay, n. sp.
Plate 92, figures 1–4; plate 93, figure 1

This species is represented by 13 fragmentary specimens which show the growth stages from a coarsely ribbed, immature form to a densely ribbed, intermediate form, and then to a fairly loosely ribbed, adult form. The differences between these three growth stages are as great as those that ordinarily distinguish species.

Shell discoidal, compressed; inner whorls subovate, as wide as high; outer whorls subquadrate, slightly higher than wide, thickest on lower part of flanks, embracing about one-third; flanks flattened and nearly parallel below, converging markedly above into moderately narrow venter, venter evenly rounded on inner whorls, narrowly rounded (pl. 92, fig. 4) on outer whorls. Umbilicus wide and fairly shallow; wall fairly low, vertical at base, rounding rather abruptly into flanks. The largest specimen is septate, and the body chamber is unknown.

The smallest known whorls (pl. 92, figs. 1, 3) bear high, narrow, widely spaced ribs, which curve backward on the umbilical wall, incline forward on the flanks, and form a gentle forwardly directed sinus on the venter. Most of the ribs bifurcate near the middle of the flanks, but a few ribs on each whorl remain simple. All ribs undergo a faint diminution in strength along the midventral line to a diameter of about 105 mm.

At a diameter of about 90 mm. the density of ribbing increases abruptly and persists for about three-quarters of a whorl to a diameter of about 150 mm. where the ribbing again becomes abruptly rather widely spaced. The increased density of ribbing is produced mainly by the addition of many simple ribs originating on the umbilical wall but partly by virgatomous branching on the upper part of the flanks. This densely ribbed growth stage differs, furthermore, from the preceding growth stage by having more flexuous ribs that describe a more pronounced sinus on the venter and by having a more narrowly rounded venter.

The largest whorls at a diameter greater than 150 or 160 mm. are characterized by fairly coarse, gently flexuous ribs that are separated by interspaces about two or three times as wide. Most of the ribs bifurcate on the upper part of the flanks, but some remain simple. The ventral sinus, produced

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EXPLANATION OF PLATE 92

FIGS. *1–4—Kossmatia varicostata* Imlay, n. sp. From 2 miles west of Los Fresnos del Río Ranch, Texas Bureau Econ. Geology loc. 17252, ×¾. *1*, Lateral view of paratype, U. S. Nat. Mus. 103366. *2–4*, Cross section, lateral view and ventral view of holotype, U. S. Nat. Mus. 103364. (p. 539)

by the forward arching of the ribs, is not as pronounced as on the densely ribbed whorl and becomes less pronounced with growth. Weak constrictions present at all growth stages.

The holotype at a diameter of 150 mm. has a whorl height of 52 mm., a whorl thickness of 43 mm., and an umbilical width of 63 mm.

This species somewhat resembles *Substeueroceras santarosanum* (Burckhardt) (1906, pl. 129, pl. 53, figs. 1–4) but is a little more involute and has less flexuous ribbing, which is denser on the intermediate-sized whorls and coarser on the outer whorls. *Kossmatia victoris* Burckhardt (1906, p. 131, pl. 26, figs. 1–6; pl. 27, fig. 1) appears to have finer ribbing and a higher, more compressed whorl section. However, Burckhardt's species is based on an internal mold and is difficult to compare with the present shelled specimens. The fragment from the Mazapil region of Zacatecas that Burckhardt (1906, p. 138, pl. 39, fig. 2) compared with *Substeueroceras permulticostatum* (Steuer) (1897, p. 182, pl. 23, figs. 1, 2) of Argentina possibly represents the densely ribbed part of *Kossmatia varicostata* but more likely belongs to the finely ribbed *Substeueroceras alamitosense* (Castillo and Aguilera) (1895, p. 15, pl. 13, fig. 2) from the Sierra de Catorce of San Luis Potosí.

Types: Holotype, U. S. Nat. Mus. 103364; paratypes, U. S. Nat. Mus. 103365a, b, 103366.

Occurrence: Upper Jurassic shale and sandstone. Texas Bureau of Economic Geology localities 17252 and 17253, Placer de Guadalupe district, eastern Chihuahua, Mexico.

KOSSMATIA KINGI Imlay, n. sp.
Plate 93, figure 2; plate 94, figures 1–6

The species is represented by 20 fragmentary specimens, which show most of the growth stages. Shell discoidal, compressed; inner whorls subovate in section; outer whorls subquadrate in section, slightly higher than wide, thickest on lower fourth of flanks, embracing about one-fourth; flanks flattened below, converging slightly above, and rounding evenly into a moderately broad venter that becomes relatively more narrow during growth. Umbilicus wide and shallow; wall fairly low, vertical at base, rounding rather evenly into flanks on inner whorls but abruptly on outer whorls. Body chamber not known, as the largest fragments are septate.

The inner whorls (pl. 94, fig. 6) bear variable, strong, forwardly inclined ribs that are separated by slightly wider interspacse and do not bifurcate before reaching the line of involution. At a diameter of about 30 mm. some of the ribs bifurcate before reaching the line of involution and at greater diameters most of the ribs bifurcate or trifurcate between the middle and the upper third of the flanks. At a diameter greater than 75 mm. trifurcating ribs are more common than bifurcating ribs. The branching by three's is virgatomous, that is, the anterior branch arises considerably lower on the flanks than the posterior branches. On the inner whorls the ribs are strongest near the middle of the flanks or at the points of furcation but do not give rise to tubercles. The ribbing on the venter, not known below a diameter of 40 mm., is not appreciably reduced in strength along the midline and is arched forward as a gentle sinus that becomes more pronounced during growth.

On the outer whorls the ribs are flexuous and inclined forward. They begin at the line of involution, curve backward on the umbilical wall, incline forward slightly on the lower part of the flanks, recurve slightly, and then arch forward strongly on the venter, where they form a pronounced, forwardly directed sinus. The ribs are strong, prominent, and widely but variably sepa-

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EXPLANATION OF PLATE 93

FIG. *1*—*Kossmatia varicostata* Imlay, n. sp. Lateral view of paratype, from 2 miles west of Los Fresnos del Río Ranch, Texas Bureau Econ. Geology loc. 17253, U. S. Nat. Mus. 103365, ×¾. (p. 539)

2—*Kossmatia kingi* Imlay, n. sp. Ventral view of holotype, shown also as figure 3, plate 94, from 2 miles west of Los Fresnos del Río Ranch, Texas Bureau Econ. Geology loc. 17252, U. S. Nat. Mus. 103367, ×¾. (p. 540)

2

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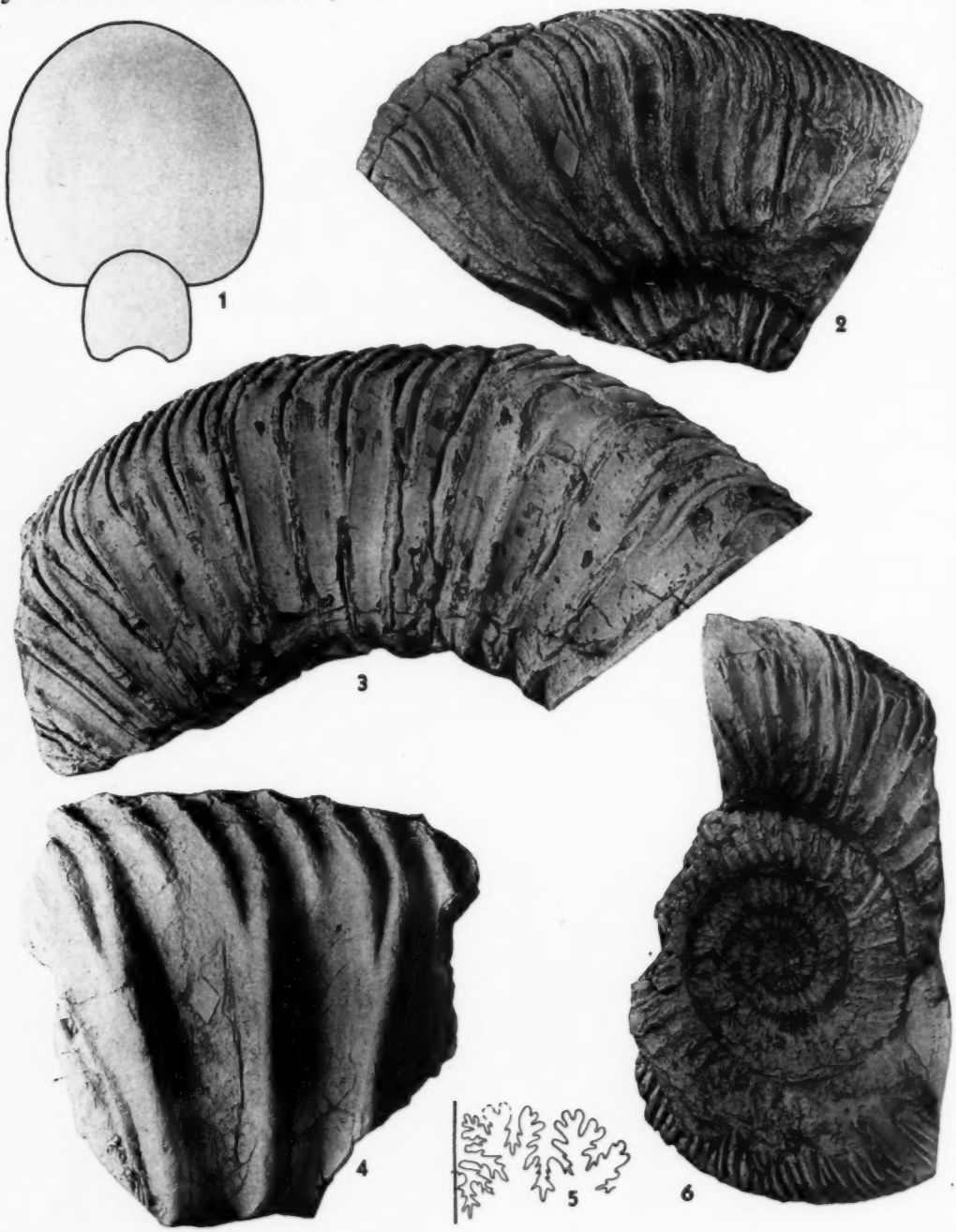
Imlay, Upper Jurassic Ammonites



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rated. The interspaces become relatively wider during growth, and on the largest whorls are about three times as wide as the ribs. During growth, the furcation points become indistinct, and consequently on the largest whorls some of the branch ribs are faintly connected. Commonly a branch rib on one flank will terminate freely on the upper third of the other flank. All ribs are of about equal strength on the upper part of the flanks and on the venter. The internal mold shows a faint thinning along the midventral line, but on the shell no thinning is apparent. Constrictions are present at all growth stages but are particularly common on the inner whorls.

The suture shown on plate 94, figure 5, was difficult to trace and is in part diagrammatic. Siphonal lobe narrow and long; first lateral lobe trifid, subsymmetrical, shorter than siphonal lobe; second lateral lobe short, oblique; ventral saddle wide, bifid, outer branch much wider than inner; first lateral saddle narrow, bifid, asymmetrical.

Dimensions of holotype and two paratypes (pl. 94, figs. 3, 2, 6) are: diameter, ?, ?, 110 (?) mm.; whorl height, 62, 53, 36 mm., whorl thickness, 64, 49, 33 mm.; umbilical width, ?, ?, 53 mm.

This species is characterized by its wide umbilicus and by its prominent, widely separated, dichotomous or virgatomous ribs. The most similar appearing species is *Kossmatia rancheriasensis* Imlay, under whose description comparisons are made.

Kossmatia burkarti Burckhardt (1906, p. 133, pl. 37, figs. 2, 5–8, 10) is similar to the inner whorls of *K. kingi* but has a more narrow and deeper umbilicus. The specimen described by Burckhardt (1906, p. 130, pl. 37, figs. 9, 11, 12) under *Perisphinctes* sp. rnd. is probably identical with *K. kingi*. *Kossmatia pectinata* Burckhardt (1912, p. 135, pl. 34, figs. 1, 7–10, 14) greatly resembles the inner whorls of *K. kingi* but is somewhat coarser ribbed.

Types: Holotype, U. S. Nat. Mus. 103367; paratypes, U. S. Nat. Mus. 103368a, b, 103369a–c.

Occurrence: Upper Jurassic shale and sandstone. Texas Bureau of Economic Geology localities 17252, 17253, 17259, Placer de Guadalupe district, eastern Chihuahua, Mexico.

KOSSMATIA RANCHERIASENSIS Imlay, n. sp.

Plate 95, figures 1, 2, 4

This species is represented by three large fragments of adult whorls. Shell discoidal; outer whorls subquadrate in outline, as high as wide, thickest on lower third of flanks; flanks flattened below, rounding evenly into fairly broad venter. Umbilical wall fairly low, rounding evenly into flanks.

The outer whorls bear strong, high, flexuous, forwardly inclined ribs that are separated by inner spaces about four times as wide. The ribs curve backward on the umbilical wall, are inflected forward near the middle of the flanks, recurve slightly on the upper part of the flanks, and then arch forward strongly on the venter. Part of the ribs are simple, but the majority bifurcate on the upper third of the flanks. Some of the furcation points are so indistinct that the anterior branch ribs are nearly separate. In addition, there are a few simple ribs which begin high on the flanks. All ribs are of about equal strength on the venter.

This species is considerably different from any described species of *Kossmatia*. It most closely resembles *K. kingi* Imlay but has wider spaced ribs that do not trifurcate and do not form as pronounced a sinus on the venter.

Holotype: U. S. Nat. Mus. 103370.

Occurrence; Upper Jurassic shale and sandstone. Texas Bureau of Economic

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EXPLANATION OF PLATE 94

FIGS. *1–6—Kossmatia kingi* Imlay, n. sp. From 2 miles west of Los Fresnos del Río Ranch, ×¾. *1, 2*, Cross section and lateral view of paratype, Texas Bureau Econ. Geology loc. 17252, U. S. Nat. Mus. 103368. *3*, Lateral view of holotype, shown also as figure 2, plate 93, Texas Bureau Econ. Geol. loc. 17252, U. S. Nat. Mus. 103367. *4*, Lateral view of paratype, Texas Bureau Econ. Geology loc. 17253, U. S. Nat. Mus. 103369. *5*, Suture of paratype, Texas Bureau Econ. Geology loc. 17252, U. S. Nat. Mus. 103368. *6*, Lateral view of paratype, Texas Bureau Econ. Geology loc. 17253, U. S. Nat. Mus. 103369. (p. 540)

Geology locality 17253, Placer de Guadalupe district, eastern Chihuahua, Mexico.

KOSSMATIA cf. K. ALAMITOSENSIS
(Castillo and Aguilera)
Plate 95, figure 3

One small specimen has strong, widely spaced, forwardly inclined ribs, of which most bifurcate a little above the middle of the flanks and form a pronounced sinus on the venter. The ribs are most elevated at the furcation points but are not tuberculated. Constrictions are present.

This specimen is possibly an immature form of *K. rancheriasensis*. Its ribbing is much like that of *K. alamitosensis* (Castillo and Aguilera) (1895, p. 30, pl. 21, figs. 4, 6), but the illustrations of the latter are too poor for positive identification. *Kossmatia interrupta* Burckhardt (1912, p. 134, pl. 34, figs. 2, 3, 15) has somewhat finer ribbing.

Figured specimen: U. S. Nat. Mus. 103371.

Occurrence: Upper Jurassic shale and sandstone. Texas Bureau of Economic Geology locality 17253, Placer de Guadalupe district, eastern Chihuahua, Mexico.

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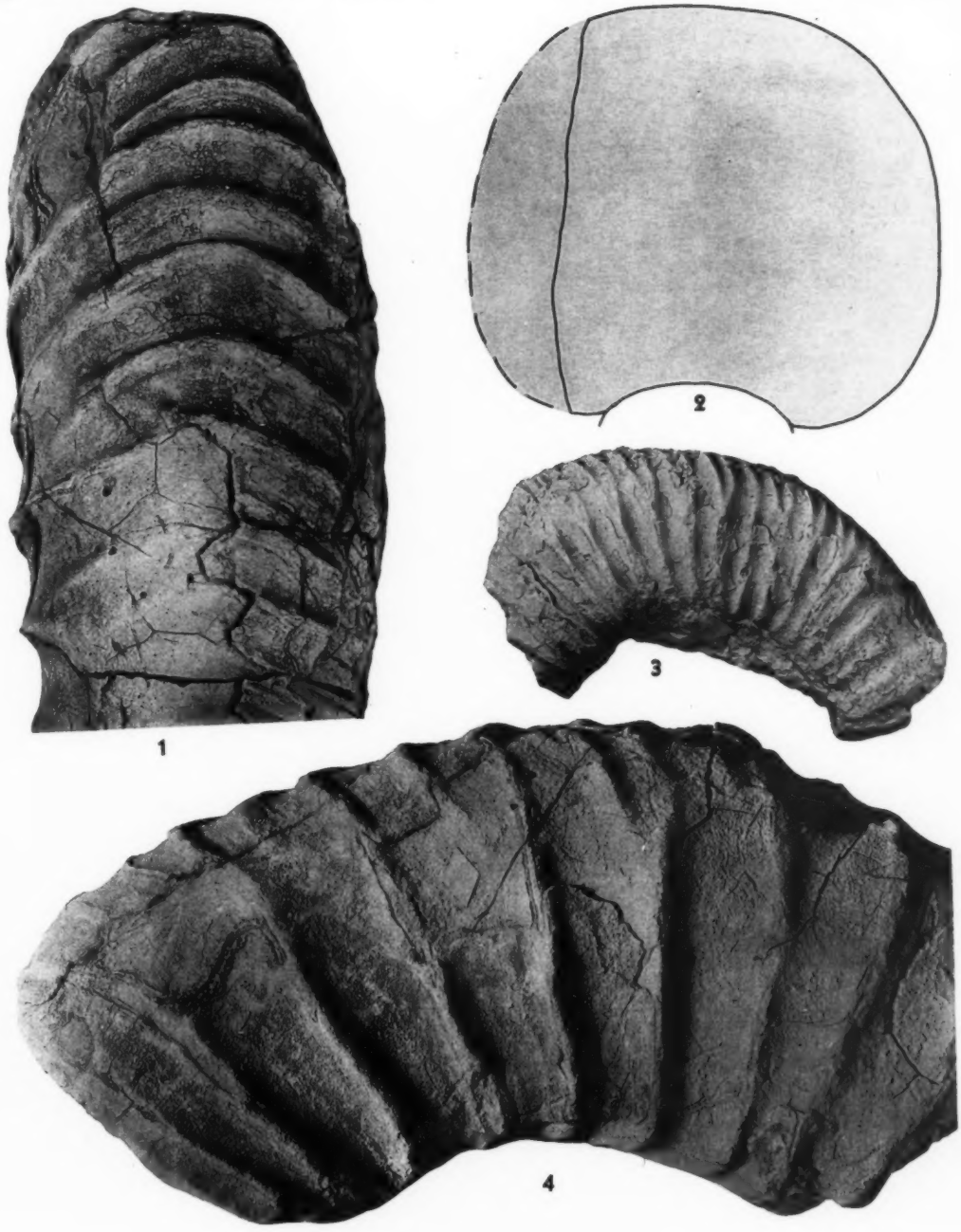
EXPLANATION OF PLATE 95

FIGS. *1, 2, 4—Kossmatia rancheriasensis* Imlay, n. sp. Ventral view, cross section, and lateral view of holotype, from 2 miles west of Los Fresnos del Río Ranch. Texas Bureau Econ. Geology loc. 17253, U. S. Nat. Mus. 103370, ×¾. (p. 541)

3—Kossmatia cf. *K. alamitosensis* (Castillo and Aguilera). Lateral view of specimen from 2 miles west of Los Fresnos del Río Ranch, Texas Bureau Econ. Geology loc. 17253, U. S. Nat. Mus. 103371, ×¾. (p. 542)



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